STUDIES IN THE ABSORPTION

OF

SURGICAL CATGUT

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by

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STUDIES IN THE ABSORPTION OF SURGICAL CATGUT

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INTRODUCTION

Since the time of Lister, and indeed from the time of Galen in the second century, much has been written concerning the absorption of surgical catgut. For the absorption of catgut and the use of catgut as a ligature and as a suture material has been the centre of many a storm of criticism and argument even to the present day. In the earlier days of its widespread use as a surgical thread in the first two decades of the present century most of the criticism was directed towards its doubtful sterility; but with the bringing of surgical catgut within the scope of the Therapeutic Substances Act and the improvement by manufacturers of the sterilising methods, however, the sterility of catgut of British and American origin is no longer disputed and attention now focuses on that property of catgut which commends its use as a ligature and suture, namely, its absorption by the body tissues.

Lister, while remaining the foremost protagonist of its use, was quick to realise that an absorbable ligature might have distinct, if not fatal, disadvantages should absorption take place before healing was far enough advanced. Realising that the problem was analogous to the tanning of leather, he experimented with various hardening agents, findsing that chromic acid (Lister, 1881) and later chromium sulphate (Lister, 1908) produced catgut strands that were not only hardened sufficiently to resist absorption while normal healing took place but were also easier to handle in that they did not become so limp in the presence of body fluids.

Howes, in a series of studies from 1928 to 1941, and Jenkins <u>et al.</u> (1937 to 1942) have done much to set the investigation of the problem of absorption on a rational and scientific basis.

Howes related the loss in tensile strength of the catgut suture to the gain in tensile strength of the healing wound and pointed out the absurdity of using stronger sutures than were necessary to hold the edges of the wound together during healing. He also pointed out many factors such as sepsis, inflammation, poor haemostasis, etc. which can have a very marked effect on the rate at which catgut is absorbed in a wound.

Jenkins surveyed the absorption in living tissues of the various brands of surgical catgut on the American market and pointed out the wide variation in properties of the various brands of catgut and demonstrated the fallacy of labelling catgut with an absorption time such as "10 day", "20 day" or "40 day". Jenkins appreciated the need for standardisation of the absorption rate by the various manufacturers and attempted to correlate the absorption <u>in vivo</u> with the resistance <u>in vitro</u> to a proteolytic enzyme such as pepsin.

Other workers, e.g. Kraissl et al. (1934 to 1938), Holder (1946) and Sizer (1945 and 1949), have modified and developed this technique and have used other enzymes such as trypsin and papain, but the fact that there are still no official standards in the U.S.A. and in Great Britain only emphasises the fact that, whereas these in vitro tests may serve a very useful purpose in controlling the absorption rate of the catgut produced by one manufacturer, there is not necessarily any correlation between these results and the results obtained on catgut prepared and sterilised by a different process.

Jenkins (1937) also appreciated the many complicating factors which may influence the absorption of a suture in a surgical wound. Indeed, in this paper, entitled "A Clinical Study of Catgut in Relation to Abdominal Wound Disruption", he discusses more than a dozen factors which may contribute to wound disruption covering surgical technique, the metabolic state of the patient, and the nature and imperfections of the suture material.

It seemed, therefore, that there was a need for an in vivo test for absorption rate which would be uncomplicated by the variables of wound healing, tension and knot tying and which would utilise small laboratory animals of a uniform strain, which would be within a comparatively narrow age and weight range. Howes and Jenkins and their co-workers used dogs as the experimental animals and, whereas the metabolism of dogs may approximate more nearly to that of human subjects, it is difficult and expensive to obtain adequate numbers of a uniform strain necessary for routine tests.

Holder (1946) used the rabbit as the experimental animal and recorded the number of stitches in the lumbar muscle breaking when subjected to traction of 450 g. applied by means of a spring balance. The time taken for the major:ity of the stitches to be reduced to a holding power of less than 450 g. was suggested as the "end point" of absorption. This conception of the "end point" was a considerable advance on the rather vague "duration of tensile strength", i.e. the time taken for reduction to zero strength, suggested by Jenkins (1942) who calculates this time from the assumption that the rate of loss of tensile strength is always constant. Holder's method of in vivo test, therefore, gives us a good qualitative method for segregating different types of catgut into three groups, corresponding roughly with the U.S.P. designations "Plain", "Medium Chromic", and "Extra Chromic". It offers, however, very little information of a quantitative nature on the rate of loss of tensile strength from day to day as absorption proceeds.

Madsen (1953) developed a method of test essentially similar to that of Holder but attempted to standardise the tension with which the suture was tied. His main interest, however, seemed to lie in the holding power of the tissues and of the knots and the types of catgut used are not the types normally used in Great Britain or in the U.S.A. and consequently his results have little information to offer.

Sizer (1945) appreciated the need for a quantitative approach to the rate of absorption and implanted catgut in the subcutaneous tissue of rabbits and frogs, withdrawing implants at various time intervals and testing the tensile strength on a reliable standard tensiometer after washing and drying the implants. Douglas (1949) used a similar method with non-absorbable sutures. The main defect in this method is that the suture material tends to be encapsulated by fibrous tissue and is difficult to remove without damage; also no attempt was made to prevent untwisting, the importance of which was strongly emphasised by Holder (1946).

It can be seen, therefore, that, although much excellent and fundamental work has been done in this field, much remains to be done before the absorption of surgical catgut is fully understood and the various factors involved fully investigated. The purpose of this introduction has been to emphasise the limitations of the work already done and to suggest the factors which need to be considered in devising an _in vivo_ test for absorption.

The limitations of the work summarised above seem to be the following:-

1. Insufficient attention seems to have been paid to the intrinsic variability of the properties,

especially the tensile strength of catgut which is a biological product and, therefore, subject to normal biological variation. As a consequence many of the results obtained are of doubtful statistical significance.

2. The unreliability of spring balances and other manually operated tensiometers has not been sufficiently appreciated. Such factors as the rate of application of the load and, very especially, the moisture content of the suture have a very marked effect on the result obtained. In this connection, the practice of drying the suture before testing is not only unrealistic, but very difficult to carry out with any degree of reproducibility.

3. Most of the work has been done on the larger laboratory animals such as rabbits and dogs which are not normally as uniform genetically as rats which have the added advantage that they can be used and stored in much larger numbers.

4. Generally speaking: the absorption problem has not been sufficiently divorced from the problems of wound healing and the problems of surgical technique, such as knot tying and the tension required to hold the wound together. It seems

that the first essential is to investigate the absorption of catgut apart from these complicat:ing factors and then to consider the effect of these factors once the normal absorption behaviour has been established.

The Criteria for a Satisfactory in vivo Absorption Test

The need is established, therefore, for an in vivo test for absorption of surgical catgut that will give a quantitative, statistically significant, indication of the rate of loss of tensile strength of the suture material in living tissues. Such a test should have the following characteristics:-

1. The technique should be relatively quick and simple and should be suitable for use in the muscle tissue of rats, but adaptable for use in other tissues and other animals such as rabbits, cats, guinea pigs, hamsters and dogs.
2. The implant should be protected from the action of the tissues except for a standard length. This protection is especially important where the implant emerges from the fascia where there tends to be a mechanical shearing action as well as the biochemical action of the tissues.
3. The catgut implant should be prevented from untwisting and should not be under tension.
4. The test for tensile strength should be done

either (a) without removal from the animal, or, if this is not practicable, (b) immediately after removal, or after storage for a limited length of time in such conditions as will prevent changes in the moisture or fluid content of the catgut. Removal from the animal should be effected without damage to the suture material.

5. The test for tensile strength should be done on a standard power-driven tensiometer.
6. The animals should not be used again for absorption tests.

<u>The Purpose of the Present Work</u>

The purpose of this work is, therefore:-

1. To devise a standard technique for testing the rate of absorption of surgical catgut, bearing in mind the criteria listed above.
2. To study the histological changes accompanying absorption.
3. Using selected batches of catgut, to study:-
    a. the difference in behaviour between plain and chromic catgut.
    b. the effect of the diameter of the suture.
    c. the effect of sex and body-weight of the experimental animals.

4. Having established the normal absorption behaviour of the catgut to investigate:

   a. the effect of an incision in the muscle tissue.

   b. the effect of sensitisation by a previous implant of catgut.

   c. the effect of alteration of the body temperature of the animal.

   d. the effect of isolating the implant from body cells but not from body fluids.

5. To study <u>in vitro</u> the effect of various fluids and enzymes on the tensile strength of catgut.

THE PREPARATION AND PROPERTIES OF THE CATGUT USED IN THESE STUDIES

The method of preparation and the method of sterilisation of surgical catgut are the major factors determining the resistance of the finished suture to absorption by the body tissues. It is important, therefore, to specify these methods in any experimental work dealing with the absorption of catgut. The following is an outline of the processes used in the preparation of the catgut for these studies.

The catgut was prepared by normal commercial practice from a single lot of sheep intestines, all of similar origin.

The submucosa was separated from the unwanted layers by soaking in dilute sodium carbonate solution, splitting into ribbons and scraping mechanically. After looping several ribbons together, the number of ribbons in each strand depending on the size of catgut required, the ribbons that were to be made into medium chromic catgut were chromicised by soaking in a solution of chromium sulphate of approximately 33% basicity.

The strands were then twisted and dried under tension and, in order to eliminate diameter variations, polished according to U.S. Patent No. 2,355,970, giving a uniformity of diameter of ± 0.005 mm.

The catgut so produced was then cut up into 4" lengths for tensile strength implants, and into 10" lengths for histological implants. Straight, round bodied 40 mm. eyeless needles were attached to the latter.

The 4" lengths were thoroughly mixed together in a large box to effect randomisation and so to minimise the effect of variation in properties from strand to strand.

Ten 4" lengths or two 10" lengths were placed in each glass tube and sterilisation effected by first drying the sutures in a hot air oven and then heating in an anhydrous petroleum fluid at a temperature of 155°C. for 1 hour.

After draining off the petroleum, the sutures were covered with sterile 90% isopropyl alcohol and the glass tubes hermetically sealed. Full aseptic precautions were taken during all operations taking place after sterilisation.

Random samples of each size were tested for sterility at this stage and were found to be sterile.

The catgut thus prepared was similar in preparation and properties to the bulk of surgical catgut manufactured commercially in Great Britain and in the United States of America. The plain gut corresponds to that designated "Type A" in the U.S.P. and the medium chromic to that designated "Type C".

TABLE I - Some properties of the catgut used in these studies

Type	Size	Diameter (mm.)	Tensile Strength (Kg.)		% Chromium (As Cr_2O_3)	Resistance to 3% Papain Solution (hours)
			Knot	Straight		
Plain	5/0	0.165	0.48	0.68	-	2.08
Plain	3/0	0.305	1.27	2.09	-	4.13
Plain	0	0.482	2.75	4.05	-	5.23
Plain	2	0.660	4.45	6.23	-	5.28
Medium Chromic	5/0	0.165	0.47	0.69	0.62	7.27
Medium Chromic	3/0	0.305	1.30	2.02	0.63	10.45
Medium Chromic	0	0.482	3.03	4.46	0.61	9.45
Medium Chromic	2	0.660	4.84	7.22	0.43	9.53

PART I

"IN VIVO" STUDIES

DEVELOPMENT AND DESCRIPTION OF IMPLANTATION TECHNIQUE

It was first attempted to devise a test in which the suture could be tested for tensile strength without removal from the animal and in which the ends of the implant were protected by polythene tubing.

Two small transverse incisions were made about 4 cm. apart at either end of the lumbar muscle (fig. 1, p. 20). A large hypodermic needle with a bore slightly greater than the diameter of the polythene tubing was passed through one incision into the muscle and out through the other incision. The catgut, size 3/0, with its polythene protectors, was passed through the needle and the needle withdrawn leaving the implant in the muscle (fig. 2, p. 20). The incisions were closed with size 3/0 non-capillary silk and the polythene was anchored to the skin with the same suture material.

This method was unsatisfactory in that it was found that manipulating the animal into a suitable position on the tensiometer usually subjected the suture to considerable strain. The protruding ends of the polythene tubing also seemed to be a source of irritation to the rats and it was found impossible to stop them biting the implants. The looseness of the skin was also a drawback in anchoring the implants.

It was, therefore, decided to concentrate on devising a technique that would facilitate the removal of the implant from the animal without damage to the suture, rather than on trying to test the tensile strength of the implant <u>in</u>

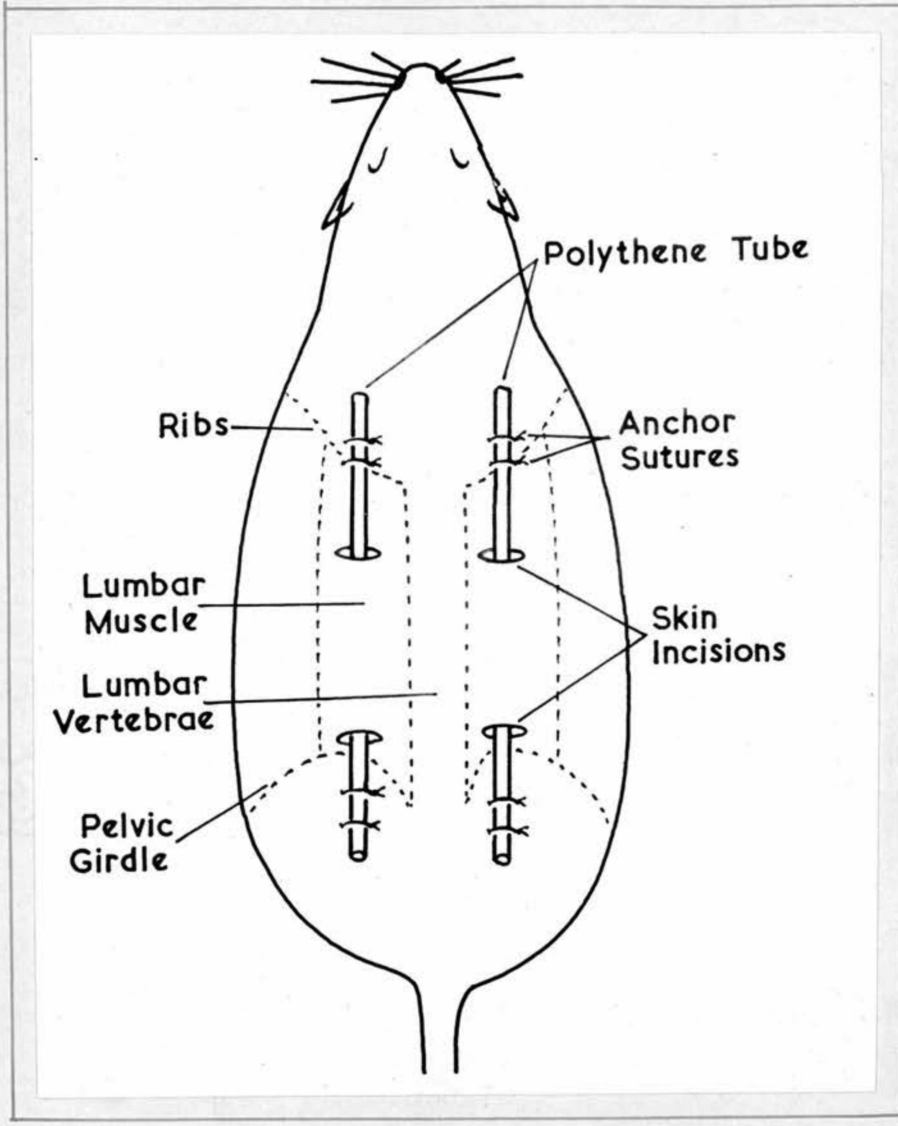


Fig. 1 - Showing position of implants

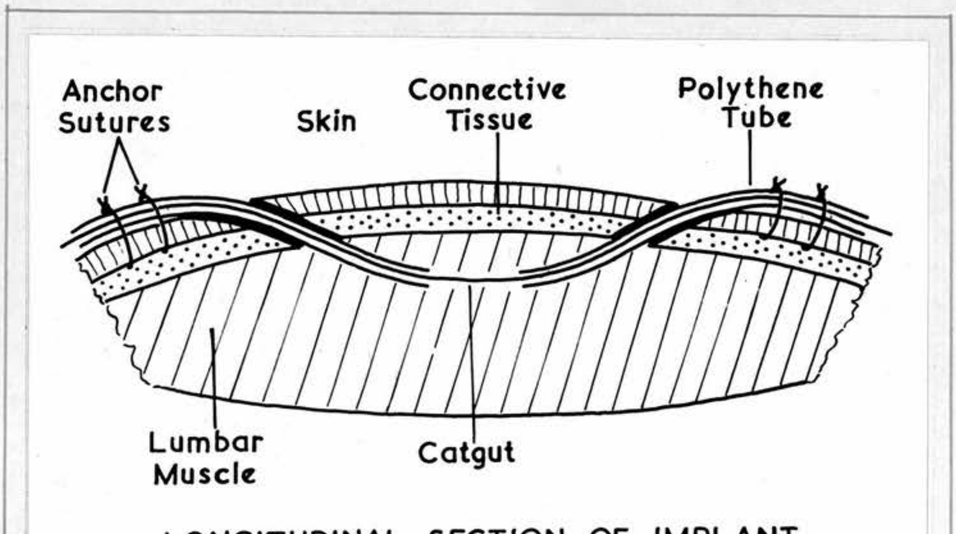


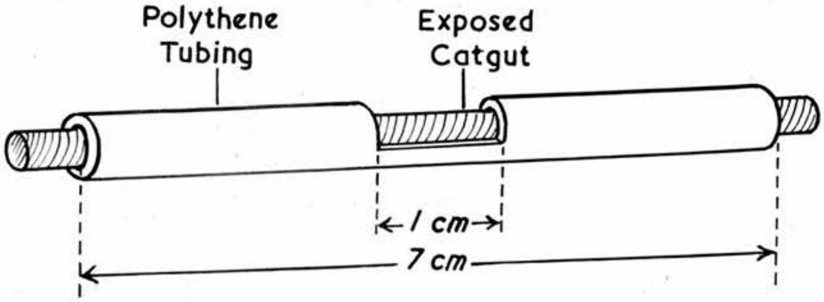
Fig. 2

<u>situ</u>.

This was accomplished by first threading the catgut through a piece of sterile polythene tubing cut as in fig. 3 (p. 22). (The polythene was sterilised by the method outlined in Appendix 1.) A longitudinal incision about 4 cm. long was made in the prepared skin of the rat over the lumbar vertebrae and the subcutaneous connective tissue broken down by blunt dissection in the lumbar area (fig. 4, p. 22).

The implant with its polythene protector was then inserted in the lumbar muscle as before and anchored by two silver haemostasis clips. Two such implants were made in each lumbar muscle and the skin closed over them by means of 3/0 non-capillary silk (figs. 5 and 6, p. 23). This technique seemed to satisfy all the criteria suggested in the previous chapter, namely:-

1. The technique was particularly suited to the use of rats as the experimental animal but could be freely adapted for use in rabbits, guinea pigs, hamsters, cats, dogs, etc. if necessary.
2. The implant was readily removable without damage to the suture and could either be tested immediately or stored for a limited period between damp gauze.
3. A standard length of suture was exposed to the body tissues leaving virtually unaffected



CATGUT IMPLANT WITH POLYTHENE PROTECTOR

Fig. 3

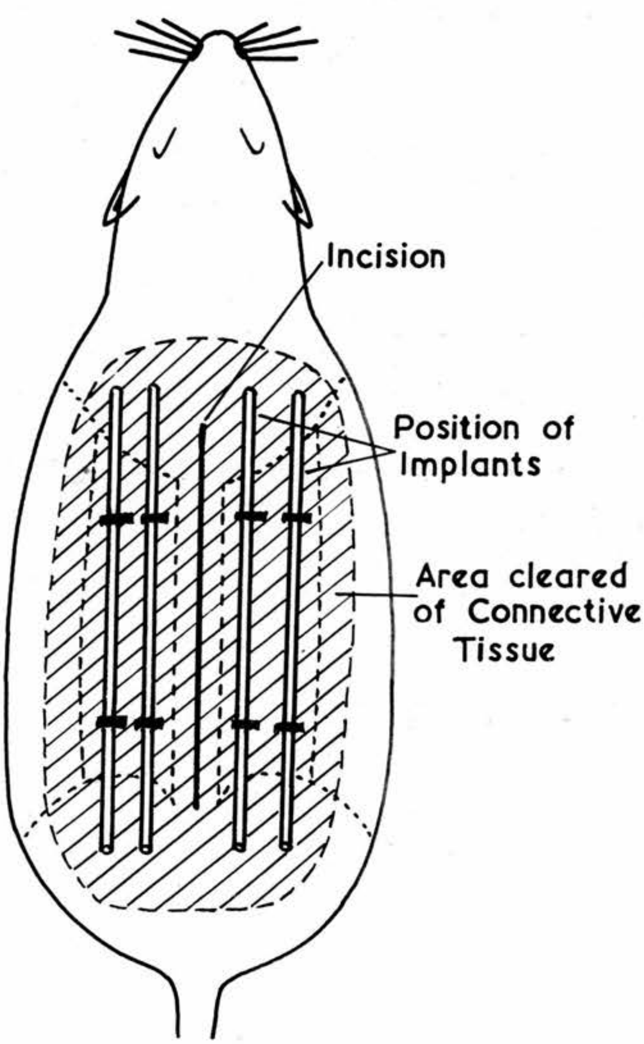


DIAGRAM SHOWING POSITION OF INCISION AND IMPLANTS

Fig. 4

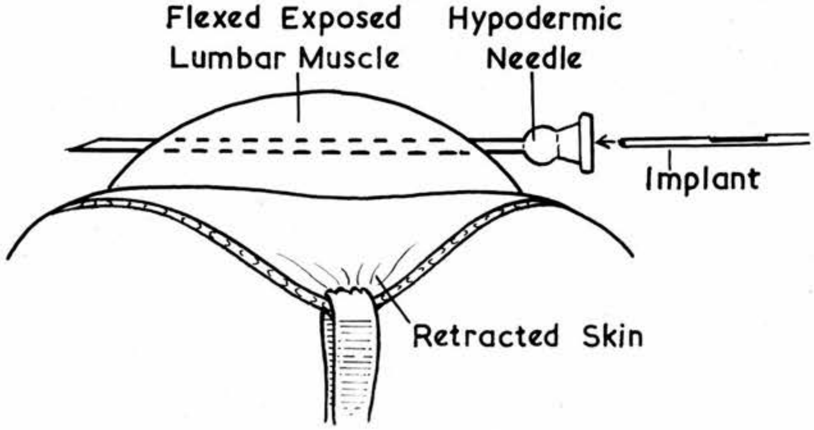
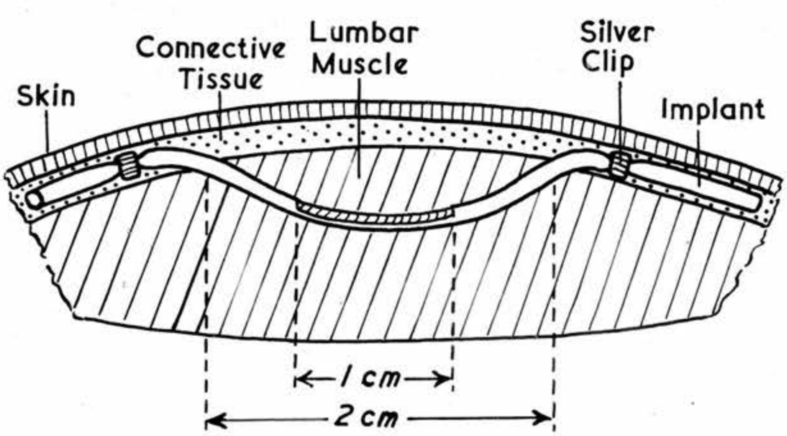


DIAGRAM SHOWING FLEXION OF LUMBAR MUSCLE AND INSERTION OF HYPODERMIC NEEDLE

Fig. 5



LONGITUDINAL SECTION SHOWING POSITION OF IMPLANT IN THE MUSCLE

Fig. 6

suture to be gripped by the clamps of the tensiometer.

4. The haemostasis clips prevented untwisting of the catgut.

5. The tensile strength could be measured accurately on a standard tensiometer.

6. The implant was not irritant to the animal and there was little chance of the implant becoming infected from external sources.

In order to facilitate the insertion of the hypodermic needle an operating table was made of 3/16" "Perspex" over which the rat could be flexed in the lumbar region (figs. 7 and 8, p. 25). The hinged flap was added to the table so that the animal's head might be kept raised, except when the needle was actually being inserted, as it was found that if the animal's head were kept hanging downwards for a prolonged period asphyxiation frequently took place.

A needle holder was also designed to make manipulation of the hypodermic needle easier, and was constructed from a pair of large Spencer-Wells forceps. The forceps were cut short and drilled as in fig. 9 (p. 26).

Standard Technique

The standard technique of implantation in these studies was, therefore, as follows:-

1. Albino Wistar rats having body-weight in the region of 150 to 250 g. were used.

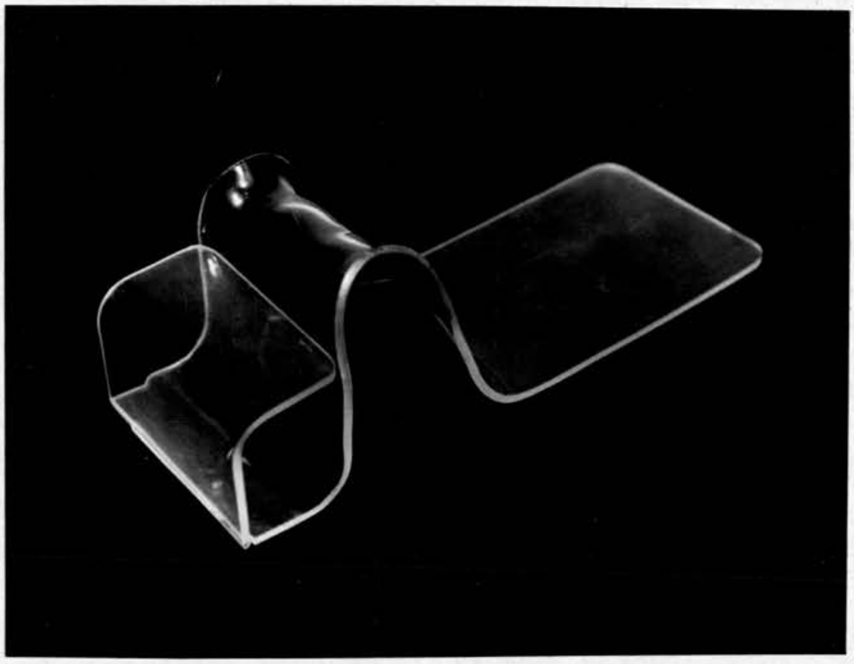


Fig. 7 - Perspex Operating Table

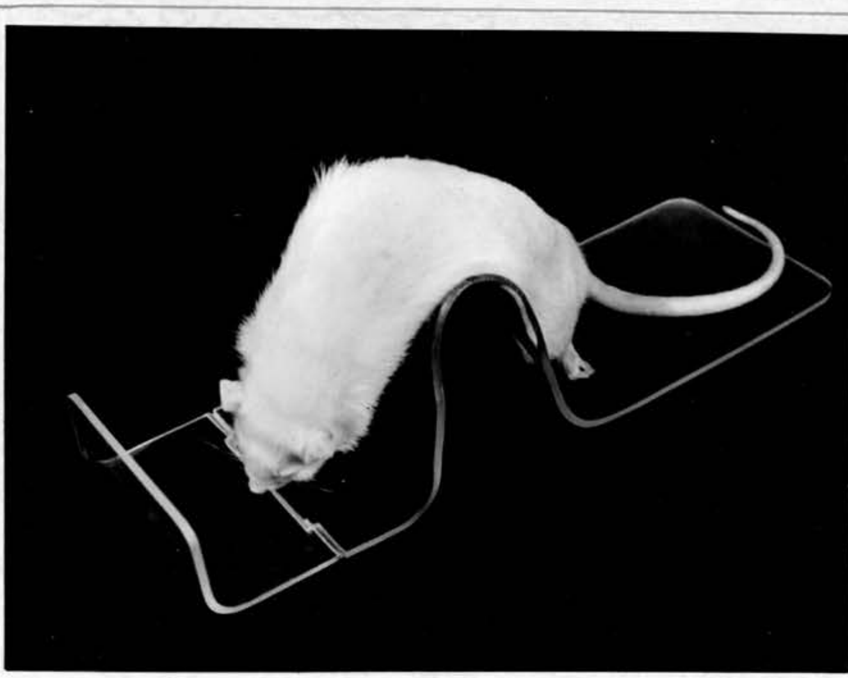


Fig. 8 - Table showing Rat in position

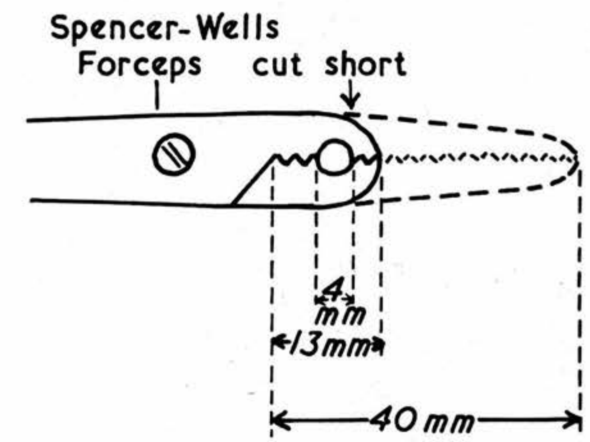


DIAGRAM OF HYPODERMIC NEEDLE HOLDER

Fig. 9

2. The rat was anaesthetised with ether and the skin covering the lumbar region prepared by shaving and swabbing with 1% alcoholic iodine solution.
3. The rat was placed on the table with the "flap" raised.
4. Using full aseptic precautions a longitudinal incision about 4 cm. long was made in the skin in the mid-line above the lumbar vertebrae. The skin was retracted and the surrounding subcutaneous connective tissue broken down by blunt dissection.
5. The table "flap" was then lowered, if necessary, and a hypodermic needle of slightly more than 1 mm. bore inserted longitudinally through the lumbar muscle, taking a "bite" of about 2 cm. and having a depth in the centre of the "bite" of about 0.5 cm.
6. A piece of catgut threaded through a piece of sterile polythene tubing, having a section 1 cm. long cut out of the middle as in fig. 3 (p. 22) was then passed through the needle and the needle was withdrawn, leaving the polythene tube and catgut implanted in the muscle. Two such implants were made in each lumbar muscle; making four implants in each rat.

7. The polythene tube was then anchored by fixing a silver haemostasis clip firmly on the tube where it entered and emerged from the muscle.
8. The skin was then sutured with size 3/0 non-capillary silk and swabbed with 1% alcoholic iodine solution.
9. After the survival period the animals were killed with chloroform and after removing the silver clips, the implant was gently withdrawn and placed between layers of gauze damped with normal saline solution and tested for tensile strength within 2 hours according to Appendix 2.

(N.B. The gauze was damped sufficiently to maintain the humidity of the suture but not sufficiently to soak it.)

ABSORPTION OF CATGUT UNDER NORMAL CONDITIONS

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The Absorption Behaviour of Plain and Medium Chromic Catgut

Size 3/0 catgut was selected as the most suitable size with which to work during these studies for the following reasons:-

It was easy to manipulate and was not too bulky an implant.

The tensile strength measurements were of such an order that they all came within the 0 to 5 lb. range of the tensiometer.

Size 3/0 is one of the most used sizes in the surgical profession.

The object of this experiment was to produce graphs showing the decrease of tensile strength with time and it was decided that each point on the graph should represent an average of 20 tensile strength measurements in order to obtain a figure that was statistically sound. This, therefore, involved the use of five rats, each with four implants, for each survival period.

The following survival periods were used:-

Plain 3/0: 1, 2, 3, 5, 7, 10 and 15 days.

Medium Chromic 3/0: 1, 2, 3, 5, 7, 10, 15, 20, 25 and 30 days.

The catgut was implanted and its tensile strength measured according to the standard technique described and the results shown in Table II obtained.

TABLE II - Loss in strength *in vivo* of plain and medium chromic size 3/0 catgut

Time (days)	Plain Catgut		Medium Chromic Catgut	
	Tens. Str. (Kg.)	% Init. Str.	Tens. Str. (Kg.)	% Init. Str.
1	1.48	100	1.86	112
2	1.15	78	1.57	95
3	1.07	72	1.61	98
5	0.75	51	1.66	100
7	0.45	30	1.48	89
10	0.46	31	1.48	89
15	0.27	18	1.20	73
20	-	-	0.87	53
25	-	-	0.44	27
30	-	-	0.20	12
	Init. Str. 1.48 Kg.		Init. Str. 1.66 Kg.	

N.B. The "initial tensile strength" is the average tensile strength of the catgut after soaking in plasma for 24 hours according to the technique described on page 79.

These results are shown graphically in figs. 10, 11 and 12 (pp. 31 and 32).

Fig. 10 (p. 31) shows the tensile strength of plain catgut plotted against the time and it can be seen that the tensile strength falls off rapidly during the first 7 days and that the curve is the typical shape of a logarithmic relationship. Fig. 11 (p. 31) shows the tensile strength plotted against the

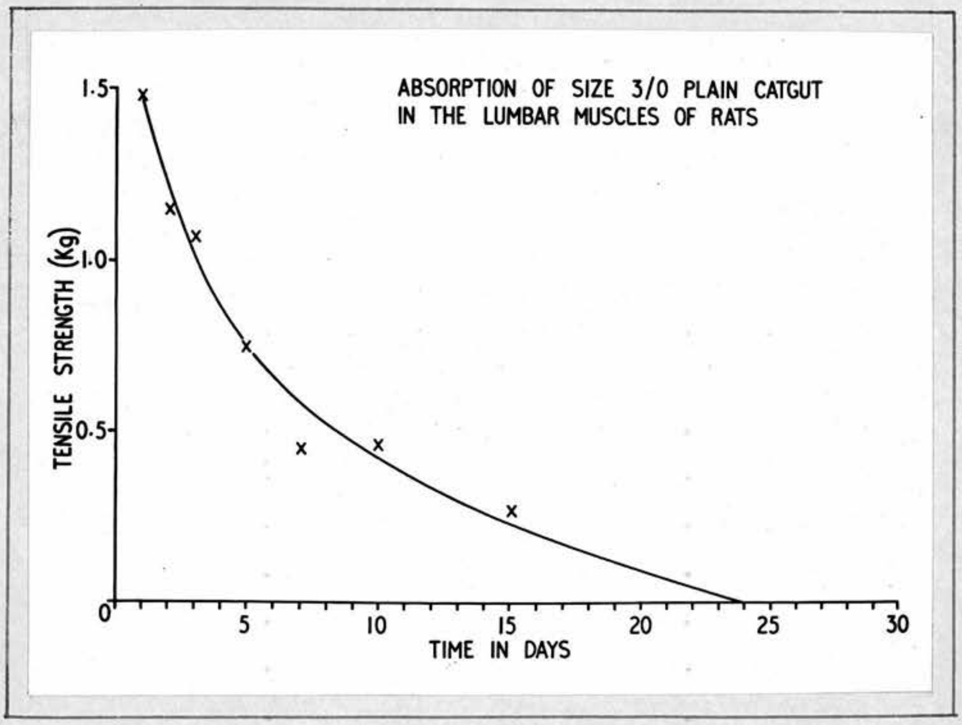

ABSORPTION OF SIZE 3/0 PLAIN CATGUT
IN THE LUMBAR MUSCLES OF RATS
TENSILE STRENGTH (Kg)
1.5
1.0
0.5
0
5
10
15
20
25
30
TIME IN DAYS

Fig. 10

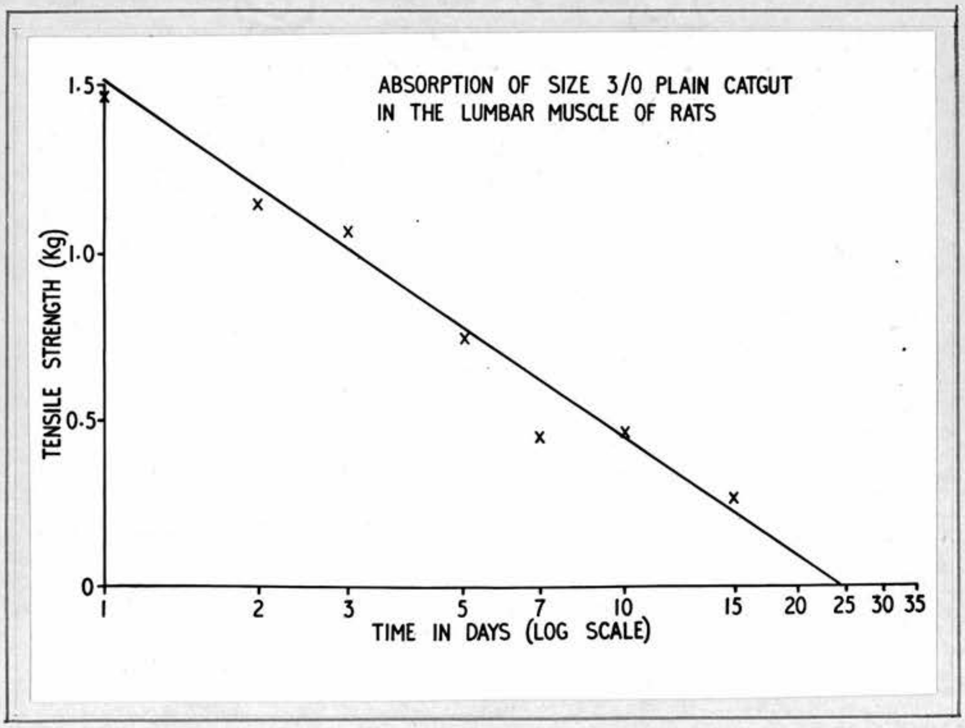

ABSORPTION OF SIZE 3/0 PLAIN CATGUT
IN THE LUMBAR MUSCLE OF RATS
TENSILE STRENGTH (Kg)
1.5
1.0
0.5
0
1
2
3
5
7
10
15
20
25
30
35
TIME IN DAYS (LOG SCALE)

Fig. 11

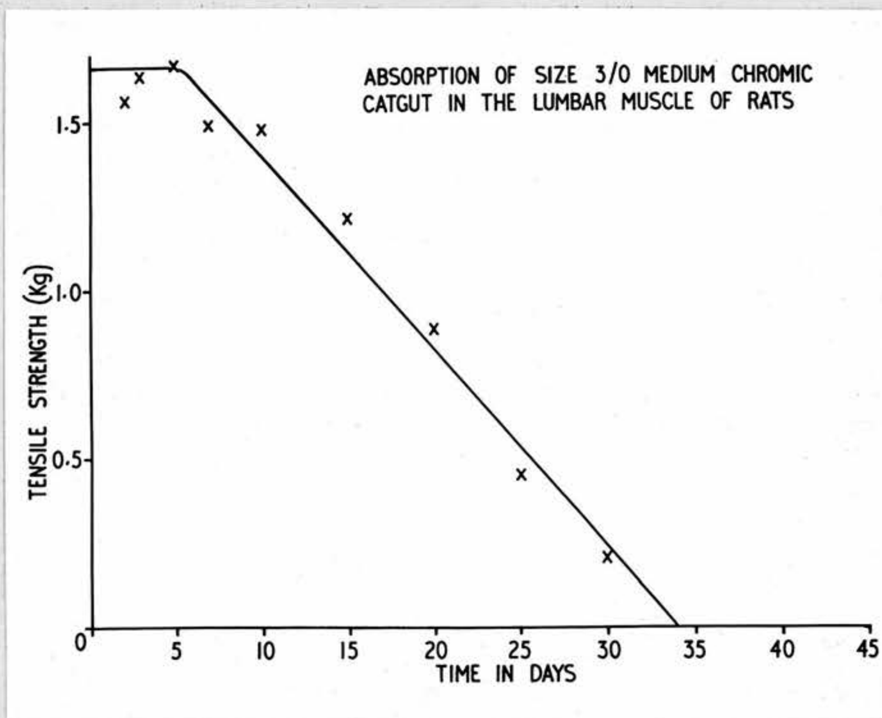

ABSORPTION OF SIZE 3/0 MEDIUM CHROMIC
CATGUT IN THE LUMBAR MUSCLE OF RATS
TENSILE STRENGTH (Kg)
1.5
1.0
0.5
0
5
10
15
20
25
30
35
40
45
TIME IN DAYS

Fig. 12

logarithm of the time and the points show a good approximation to a straight line. The "best straight line" was fitted to these points by the method of least squares.
Fig. 12 (p. 32) shows the tensile strength of medium chromic catgut plotted against the time and it can be seen that the tensile strength is almost unchanged for about 5 days and thereafter declines almost linearly with time.

The normal behaviour of the size 3/0 plain catgut in muscle tissue, therefore, is that the tensile strength declines in proportion to the logarithm of the time, reaching zero strength in about 24 days. There seems to be a very brief period of about 1 day in which there is no loss of tensile strength. The time taken for the reduction of the tensile strength to half its initial value is approximately 5 days.

The normal behvaiour of the size 3/0 medium chromic catgut in muscle tissue is that the tensile strength is virtually unchanged for about 5 days and thereafter declines in direct proportion to the time, reaching zero strength in about 34 days. The time for reduction to half the initial strength is approximately 20 days.

It may be noted that, although the tensile strengths of plain and medium chromic catgut were virtually the same when measured "dry" directly from the tube, the strength of the medium chromic catgut was about 12% higher than that of the plain catgut after both had been in contact with plasma for 24 hours; so that in actual use medium chromic is stronger than plain catgut of equivalent size.

The Effect of the Diameter of the Catgut

Four different sizes of catgut in plain and medium chromic catgut were used in these experiments, the diameters of which are shown in Table III below.

TABLE III - Diameters of the sizes of catgut used.

Size	Diameters	
	mm.	inches
5/0	0.165	0.0065
3/0	0.305	0.0120
0	0.482	0.0190
2	0.660	0.0260

Implants were made by the standard technique, size 2 catgut requiring polythene tubing of 1 mm. bore instead of the normal 0.5 mm. bore. (See Note at the end of chapter.)

The results for size 3/0 had already been determined in the previous experiments.

The following survival periods were used:-

Plain 5/0, 0 and 2: 1, 2, 3, 5, 7, 10 and 15 days and in addition sizes 0 and 2 had periods of 20 and 25 days.

Medium chromic 5/0, 0 and 2: 1, 2, 3, 5, 7, 10, 15, 20, 25 and 30 days and in addition sizes 0 and 2 had periods of 35 and 40 days.

Tables IV and V show the results obtained and these results are demonstrated graphically in figs. 13 and 14 (p.38).

<u>TABLE IV</u> - Loss of strength <u>in vivo</u> of plain catgut

Time (days)	Size 5/0		Size 3/0		Size 0		Size 2	
	Tens. Str. (Kg.)*	% Init. Str.	Tens. Str. (Kg.)*	% Init. Str.	Tens. Str. (Kg.)*	% Init. Str.	Tens. Str. (Kg.)*	% Init. Str.
1	0.50	100	1.48	100	3.84	100	5.07	100
2	0.34	67	1.15	78	3.60	94	4.92	97
3	0.29	58	1.07	72	3.23	84	4.15	82
5	0.11	22	0.75	51	2.30	60	3.99	79
7	0.11	22	0.45	30	2.11	55	2.57	51
10	0.08	17	0.46	31	2.06	54	1.84	36
15	0.02	4	0.27	18	0.78	20	0.33	6
20	-	-	-	-	0.46	12	0.51	10
25	-	-	-	-	0.04	1	0.00	0
	Init. Str. 0.50 Kg.		Init. Str. 1.48 Kg.		Init. Str. 3.84 Kg.		Init. Str. 5.10 Kg.	

*Each figure is the average of 20 determinations.

<u>TABLE V</u> - Loss of strength <u>in vivo</u> of medium chromic catgut

Time (days)	Size 5/0		Size 3/0		Size 0		Size 2	
	Tens. Str. (Kg.)*	% Init. Str.	Tens. Str. (Kg.)*	% Init. Str.	Tens. Str. (Kg.)*	% Init. Str.	Tens. Str. (Kg.)*	% Init. Str.
1	0.43	93	1.86	112	3.82	106	6.00	100
2	0.50	108	1.57	95	3.55	99	6.23	105
3	0.38	84	1.61	98	3.58	99	5.98	100
5	0.46	100	1.66	100	3.06	85	5.60	94
7	0.37	80	1.48	89	3.36	93	5.58	93
10	0.40	86	1.48	89	3.06	85	4.96	83
15	0.24	52	1.20	73	1.80	50	3.24	54
20	0.31	67	0.87	53	1.15	32	2.84	47
25	0.10	22	0.44	27	0.97	27	2.01	33
30	0.09	19	0.20	12	0.10	3	0.75	14
35	-	-	-	-	0.02	0.5	0.50	8
40	-	-	-	-	0.14	4	0.20	3
	Init. Str. 0.46 Kg.		Init. Str. 1.66 Kg.		Init. Str. 3.60 Kg.		Init. Str. 6.00 Kg.	

*Each figure is the average of 20 determinations.

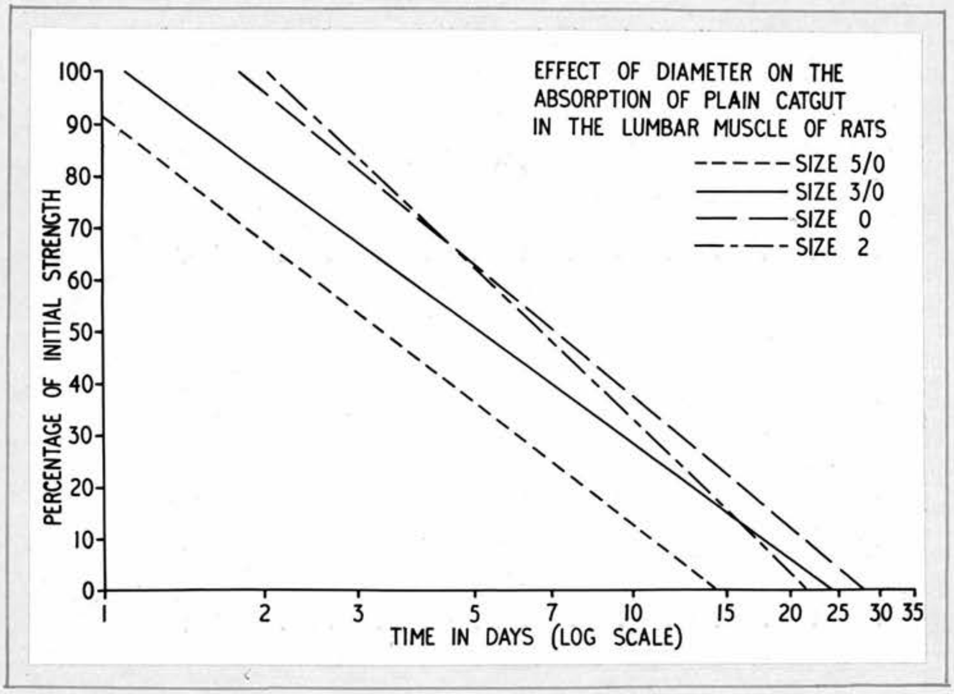

EFFECT OF DIAMETER ON THE ABSORPTION OF PLAIN CATGUT IN THE LUMBAR MUSCLE OF RATS
SIZE 5/0
SIZE 3/0
SIZE 0
SIZE 2
PERCENTAGE OF INITIAL STRENGTH
TIME IN DAYS (LOG SCALE)

Fig. 13

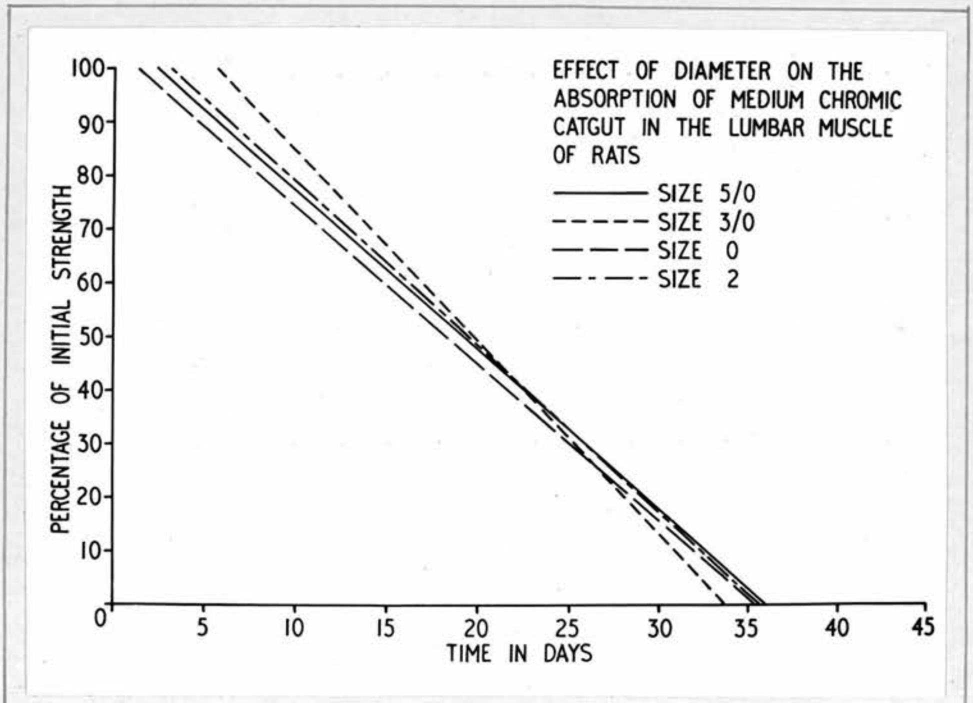

EFFECT OF DIAMETER ON THE ABSORPTION OF MEDIUM CHROMIC CATGUT IN THE LUMBAR MUSCLE OF RATS
SIZE 5/0
SIZE 3/0
SIZE 0
SIZE 2
PERCENTAGE OF INITIAL STRENGTH
TIME IN DAYS

Fig. 14

Fig. 13 (p. 38) shows the "Percentage of Initial Strength" of various sizes of plain catgut plotted against the logarithm of the time, the best straight line being fitted to each set of points. (The points have been omitted from the graph for the sake of clarity.) The slope of the curve is similar in all cases but in the case of the thicker sizes there appears to be an "induction period" of 2 to 3 days.

Fig. 14 (p. 38) shows the "Percentage Initial Strength" of various sizes of medium chromic catgut plotted against the time and it can be seen that all the curves are almost identical.

Table VI shows some of the data that may be deduced from these experiments.

TABLE VI - Summary of some absorption characteristics of plain and medium chromic catgut.

Type	Size	Induction Period (days)	Reduction to 50% Strength (days)	Reduction to Zero Strength (days)
Plain	5/0	Less than 1 day.	$3\frac{1}{2}$	13
Plain	3/0	1	5	24
Plain	0	2	7	28
Plain	2	$2\frac{1}{2}$	7	22
Medium Chromic	5/0	3	19	36
Medium Chromic	3/0	5	20	34
Medium Chromic	0	2	$18\frac{1}{2}$	35
Medium Chromic	2	4	$19\frac{1}{2}$	35

The absorption of plain and medium chromic catgut followed the same pattern in all four sizes. The absorption of plain catgut again exhibited the logarithmic relationship with time. The size 5/0 plain had practically no induction period and was rapidly absorbed reaching zero strength in about 13 days. The other sizes only differed in the length of the induction period, all reaching zero strength between 22 and 28 days.

The medium chromic catgut showed a very striking degree of uniformity from size to size as seen from fig. 14 (p. 38) and Table VI, all being reduced to half strength in about 19 days and to zero strength in about 35 days.

NOTE

When this experiment was carried out (1952) the range of sizes of polythene tubing was very limited, there being no intermediate sizes between 0.5 mm. and 1.0 mm. bore. A fuller range of sizes is now available (1955).

It is possible that in the case of implants of size 5/0 and size 2 that more than the "standard length" of catgut (p. 12) was exposed to proteolytic action because of infiltration of fluids and cells into the comparatively wide space (0.17 mm.) between the catgut and the polythene wall. In order to test the validity of the previous experiment the following experiments were performed.

1. Lengths of plain catgut, size 5/0 and size 2, with their polythene protectors, were placed

between gauze pads which had been liberally soaked in plasma coloured with methylene blue.

<u>Result</u>: In all cases the fluid was drawn by capillarity into the tube between the catgut and the polythene wall.

2. Implants of size 5/0 and size 2 plain catgut were made in normal rats. 24 hours before killing a subcutaneous injection of 1.0 ml. of 0.06% Evans' Blue solution in normal saline was made in the lumbar region. Survival periods of 1 day and 5 days for size 5/0 and 1 day and 10 days for size 2 were used and four rats for each survival period. After removal the implants were examined for the presence of colour, fluid and cells.

<u>Results</u>

a. After 1 day: The ends of the polythene implant as far as the silver clip contained a certain amount of blue fluid. In the portion of the implant between the clips there was no blue fluid but there was a certain amount of blood and traces of cellular material attached to the catgut inside the polythene tube.

b. After 5 days (size 5/0) and 10 days (size 2): The blue dye did not permeate to any part of the implant. There was loose growth of cellular elements not only over the "standard length" but inwards into the polythene tube.

3. Implants of size 5/0 and size 2 plain catgut were made in normal rats and removed after 5 and 10 days in the case of size 5/0 and 10 and 15 days in the case of size 2. Four rats were used for each survival period. After removal of the implants from the animal the catgut was very carefully withdrawn from the polythene protector and examined microscopically to determine the extent of actual physical attack.

<u>Results</u>: In all cases, although considerable cellular material and fluids had infiltrated into the space between the catgut and the polythene wall, the actual attack of the catgut itself was limited to the area exposed to the tissues at the cut-away portion of the polythene tube.

Figs. 15 and 16 are photographs of the polythene tube and its catgut insertion

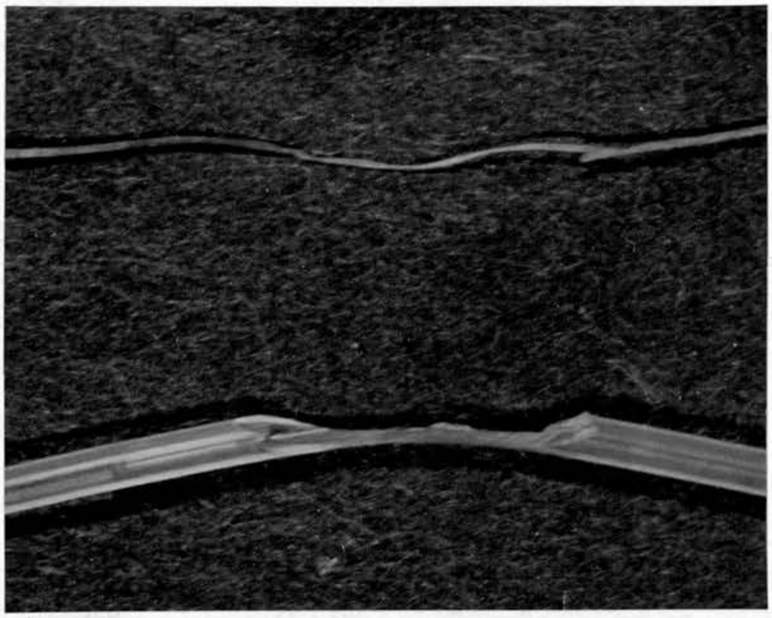


Fig. 15: Size 5/0 Plain Catgut and its
Polythene Protector after 10 Days

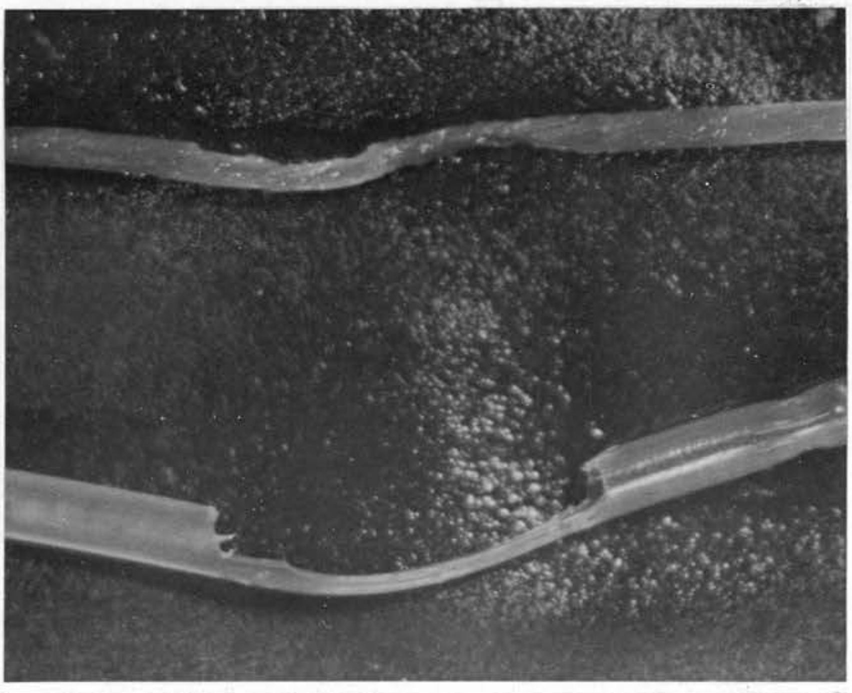


Fig. 16: Size 2 Plain Catgut and its
Polythene Protector after 15 Days

showing that erosion of the catgut was confined to that area which was exposed to the tissues through the cut-away portion of the polythene tube.

Conclusion

These experiments demonstrate that the protection afforded by the rather over-size polythene protectors in the previous experiment was adequate.

The Effect of the Sex of the Animal

It was not possible to use animals all of the same sex in these studies and the males and females were not distributed in any orderly manner throughout the experiments. The sex of each animal, however, was noted at post-mortem examination and any possible effect of sex on the absorption rate investigated by means of a statistical analysis (see Appendix 4).

When the male and female groups were considered separately relative to the regression equation they were found to differ significantly from each other in respect of the scatter of the tensile strength results but not in respect of the average tensile strength, the results from the male rats being more widely scattered than those from the female rats in both plain and medium chromic experiments.

The effect on the final result was, therefore, negligible, but there might be added precision if only female rats were used.

The Effect of Body Weight

The body-weights of the animals varied from about 120 g. to 450 g., the majority being in the range of 150 g. to 250 g. A statistical analysis of the factors of time, tensile strength and body-weight showed that in the case of the absorption of plain catgut there was no significant effect of body-weight. In the case of the absorption of medium chromic catgut, however, there did seem to be an apparent decrease of absorption rate with increased body-weight which appeared to be significant.

It was felt, in this case, that there might be other factors involved, e.g. a slight difference in the strain of rat, which were not allowed for in the analysis of the results.

The Precision of the Method

Variability of Measurements

It would be expected that the tensile strength measurements of the implants would become less widely scattered as the average strength decreased. In actual fact, however, there was no evidence of this until the average strength fell below about 0.75 Kg. Above that, the scatter, as reflected by the variance, appeared to be independent of the average strength.

The Accuracy of Measurement of Absorption Time

It has already been stated that, in the case of plain catgut, there is a direct relationship between average tensile strength and the logarithm of the time.

The relationship between time and tensile strength is not quite so simple in the case of medium chromic catgut. Probably the curve produced when average tensile strength is plotted against time is an S-shaped curve, and a parabola also fits the points quite well. For practical purposes, however, a curve showing an "induction period" followed by a straight line is a sufficiently accurate representation, especially in the middle portion of the straight line.

The accuracy of measurement of the time for reduction of the tensile strength to 50% of its original value was considered to be the most useful figure to determine as it was intended to express absorption time in these terms.

The time for reduction to 50% strength was read from the appropriate graphs of tensile strength plotted against time (see Table VI).

The standard deviation of the average strength for this time was calculated for each size and the range of tensile strength to include 19 out of 20 determinations of the average strength calculated from the standard deviation. The range of time corresponding to this range of tensile strength was then read from the appropriate graph.

The results are shown in Table VII.

The accuracy varies a little from size to size but is of the order of $+2\frac{1}{2}$ to $-1\frac{1}{2}$ days for most sizes of plain catgut and of the order of $\pm$ 3 to 4 days for medium chromic catgut.

TABLE VII - Accuracy of measurement of 50% absorption time

Type	Size	Standard Deviation of the av. tensile strength (Kg.)	Range to include 19 out of 20 averages (Kg.)	Time for 50% Absorption (days)	Range to include 19 out of 20 averages (days)
Plain	5/0	0.033	± 0.06	3.4	+1.3 to -1.0
Plain	3/0	0.092	± 0.18	5.2	+2.4 to -1.6
Plain	0	0.224	± 0.44	7.1	+2.6 to -1.9
Plain	2	0.332	± 0.65	6.8	+2.3 to -1.8
Medium Chromic	5/0	0.026	± 0.05	19.2	± 3.7
Medium Chromic	3/0	0.082	± 0.16	19.8	± 2.8
Medium Chromic	0	0.148	± 0.29	18.4	± 4.1
Medium Chromic	2	0.266	± 0.52	19.5	± 3.8

ABSORPTION OF CATGUT UNDER ABNORMAL CONDITIONS

——— oOo ———

The Effect of an Incision in the Muscle

This investigation was done concurrently with the experiments described on pages 29 - 34 using size 3/0 plain and medium chromic catgut and the results obtained in that experiment, therefore, served as "controls" for this one.

The technique used was the standard technique previously described with the difference that an incision was made transversely in the lumbar muscle involving about two thirds of the cross sectional area of the muscle (figs. 17 and 18, p. 51). After implanting the catgut in the usual way the incision was closed by suturing the fascia very carefully with interrupted sutures of size 5/0 silk attached to 16 mm. curved triangular eyeless needles.

The results are summarised in Table VIII, and expressed graphically in figs. 19 and 20 (p. 52), the "best straight line" being calculated for each set of results. It will be seen that the curves for "intact" and "incised" muscle are almost identical both for plain and medium chromic catgut. It may, therefore, be concluded that the presence of an incision by itself does not significantly affect the absorption behaviour of catgut.

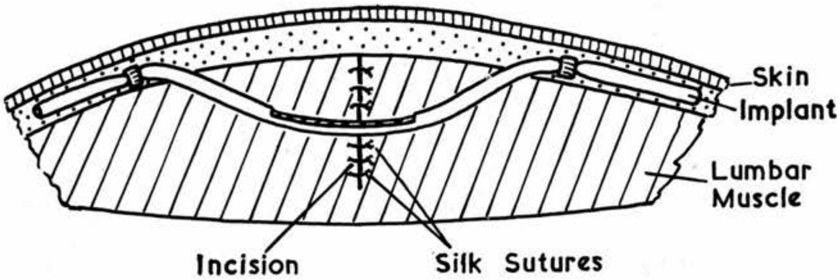


DIAGRAM SHOWING POSITION OF INCISION

Fig. 17

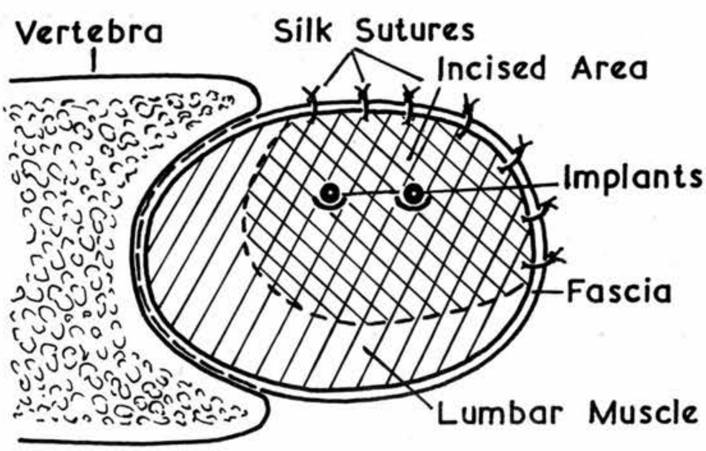


DIAGRAM OF CROSS SECTION SHOWING EXTENT OF THE INCISION IN THE LUMBAR MUSCLE

Fig. 18

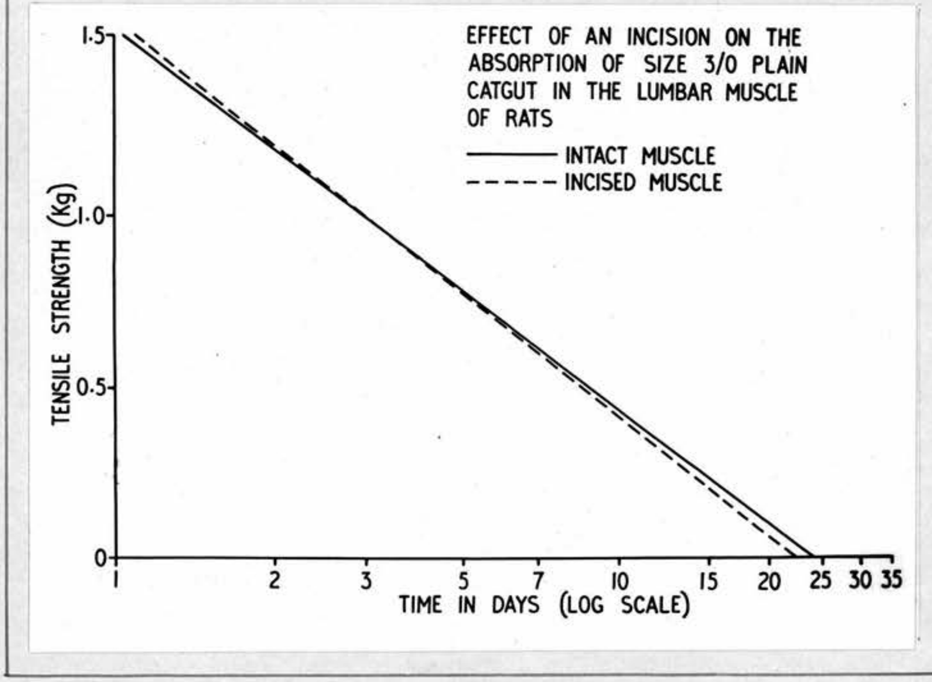

EFFECT OF AN INCISION ON THE ABSORPTION OF SIZE 3/0 PLAIN CATGUT IN THE LUMBAR MUSCLE OF RATS
INTACT MUSCLE
INCISED MUSCLE
TENSILE STRENGTH (Kg)
1.5
1.0
0.5
0
1
2
3
5
7
10
15
20
25
30
35
TIME IN DAYS (LOG SCALE)

Fig. 19

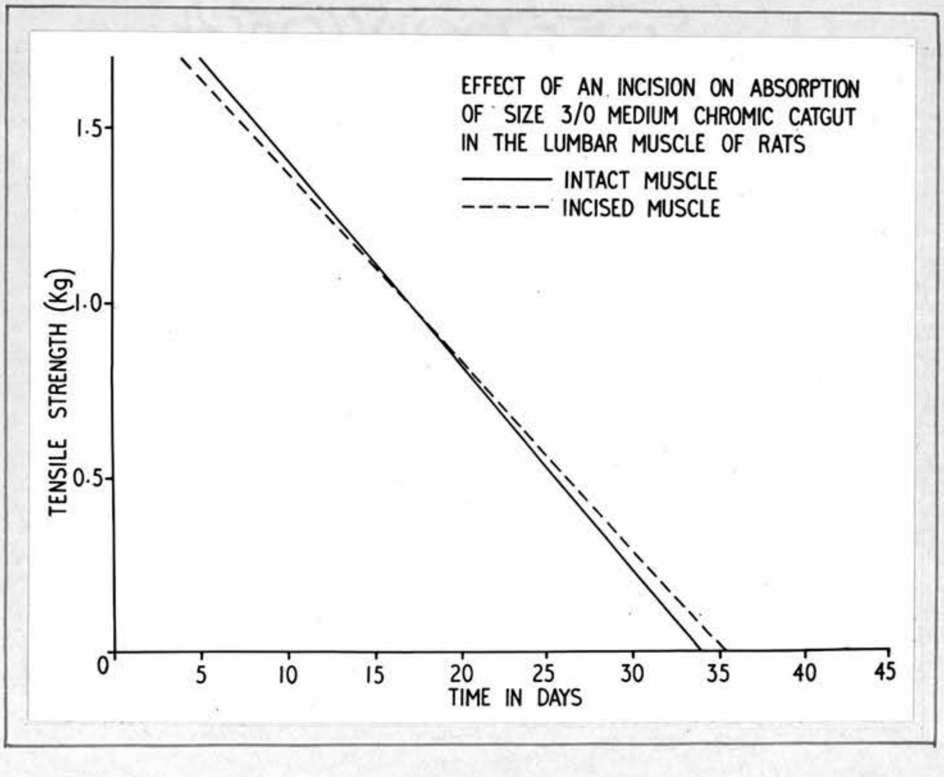

EFFECT OF AN INCISION ON ABSORPTION OF SIZE 3/0 MEDIUM CHROMIC CATGUT IN THE LUMBAR MUSCLE OF RATS
INTACT MUSCLE
INCISED MUSCLE
TENSILE STRENGTH (Kg)
1.5
1.0
0.5
0
5
10
15
20
25
30
35
40
45
TIME IN DAYS

Fig. 20

<u>TABLE VIII</u> - The effect of an incision on the loss of strength <u>in vivo</u> of catgut.

Time (days)	Plain Catgut				Medium Chromic Catgut			
	Intact Muscle		Incised Muscle		Intact Muscle		Incised Muscle	
	Tens. Str. (Kg.)*	% Init. Str.	Tens. Str. (Kg.)*	% Init. Str.	Tens. Str. (Kg.)*	% Init. Str.	Tens. Str. (Kg.)*	% Init. Str.
1	1.48	100	1.35	91	1.86	112	2.02	124
2	1.15	78	1.20	81	1.57	95	1.75	105
3	1.07	72	0.85	58	1.61	98	1.70	102
5	0.75	51	0.57	39	1.66	100	1.68	101
7	0.45	30	0.53	36	1.48	89	1.58	95
10	0.46	31	0.43	29	1.48	89	1.36	82
15	0.27	18	0.23	16	1.20	73	1.09	66
20	-	-	-	-	0.87	53	0.80	48
25	-	-	-	-	0.44	27	0.56	39
30	-	-	-	-	0.20	12	0.34	20

*Each figure is the average of 20 determinations.

The Effect of "Catgut Sensitisation"

Opinion is very sharply divided as to whether catgut sensitisation really exists. Kraissal et al. (1938) reported that sensitisation to catgut, catgut extract, and chromic acid could be produced in guinea pigs, resulting in a marked increase in the incidence of wound disruption and in abnormal healing of wounds with premature absorption of the catgut, in the sensitised animals. Skin tests on patients whose wounds had disrupted showed that 14% of these were sensitive either to catgut extract or to chromic acid and it was suggested that a history of allergy or a previous operation in which catgut had been used might be a factor in the incidence of wound rupture in some patients.

Langston (1942) made similar skin tests, using similar catgut extracts (including extracts from iodine sterilised catgut) and came to similar conclusions. Hopps (1944), in a series of studies, demonstrated that catgut and sheep serum produced hypersensitivity in rabbits and guinea pigs, shown by skin reactions and production of antibodies. He found that there was evidence of greater tissue reaction to catgut in the case of sensitised animals but that there was no appreciable difference in absorption rate between sensitised and non-sensitised animals during the critical period of healing and no significant difference in the rate of healing in wounds repaired with catgut. The absence of a significant difference he attributed to the relative insolubility of catgut.

On the other hand, Pickrell and Clay (1944) failed to produce sensitisation in rabbits or guinea pigs and failed to produce anaphylactic shock in "sensitised" guinea pigs. Their serological tests for specific antibodies were negative and they came to the conclusion that catgut merely acts as a foreign body. They also found no evidence of allergy in 35 cases of wound disruption.

Howes (1940) goes so far as to refer to the "myth of catgut allergy".

In spite of the conflicting evidence there does seem some justification for assuming that catgut sensitivity or, at least, sensitivity to some impurity in catgut does exist and that the effect of sensitisation is worth investigating in relation to the rate of absorption.

In a preliminary experiment in which a short length (about 5 or 6 cm.) of catgut was implanted in the lumbar muscle 21 days before the usual implant of plain catgut was made, the results shown in Table IX were obtained.

Although the difference between the normal and "sensitised" animals was small and probably not of sufficient statistical significance to prove anything, it was sufficient to show that a significant difference might possibly be obtained using a larger quantity of catgut for the sensitising implant.

<u>TABLE IX</u> - The effect of "catgut sensitisation" on the loss of strength <u>in vivo</u> of plain catgut.

Time (days)	Normal Rats		"Sensitised" Rats	
	Tens. Str. (Kg.)*	% Init. Str.	Tens. Str. (Kg.)*	% Init. Str.
1	1.48	100	-	-
2	1.15	78	1.28	86
3	1.07	72	1.00	68
5	0.75	51	0.55	37
7	0.45	30	0.47	32
10	0.46	31	0.12	8
15	0.27	18	0.07	5

*Each figure is the average of 20 determinations.

In the following experiments, therefore, the sensitising implant consisted of 2 coils, about ½" diameter, each consisting of a 30" length of catgut. These implants were inserted in the subcutaneous connective tissue over the gluteal muscles. 21 days later the usual implants for tensile strength measurements were made.

Statistical advice here (Dr. B. Woolf - personal communication) indicated that greater precision would be obtained, as a straight line relationship had already been established, by using fewer survival periods (only 2 would be necessary) and a larger number of animals for each survival period, provided that the "control" results so obtained did not differ significantly from the results obtained in the first experiments.

Implants of plain and medium chromic catgut were used for the sensitising implants and their effect on the absorption rate of both plain and medium chromic catgut (size 3/0) was investigated. Ten animals (i.e. 40 tensile strength measurements) were used for each survival period.

The results obtained are shown in Table X and expressed graphically in figs. 21 and 22 (p. 59).

When compared with the "controls", the absorption rate of plain catgut in animals which had been sensitised with plain catgut was <u>increased</u>. This increase in absorption rate was significant at the 0.05 level.

The absorption rate of plain catgut in animals sensitised with medium chromic catgut and of medium chromic catgut in animals sensitised with plain catgut was not significantly different from that of the "controls".

The absorption rate of medium chromic catgut in animals sensitised with medium chromic catgut, however, was <u>decreased</u>, the difference from the "controls" being significant at the 0.01 level.

TABLE X - The effect of "catgut sensitisation" on the absorption rate of catgut *in vivo*.

Type of Catgut		Tensile Strength (Kg.)*			Time for Reduction to Half Initial Strength (days)
Sensitising Implant	Tensile Strength Implant	2 days	7 days	25 days	
None (Control)	Plain	1.25	0.58		5
Plain	Plain	0.97	0.33		3
Medium Chromic	Plain	1.22	0.65		$5\frac{1}{2}$
None (Control)	Medium Chromic		1.53	0.50	19
Medium Chromic	Medium Chromic		1.60	0.85	25
Plain	Medium Chromic		1.59	0.65	21

*Each figure is the average of 40 determinations.

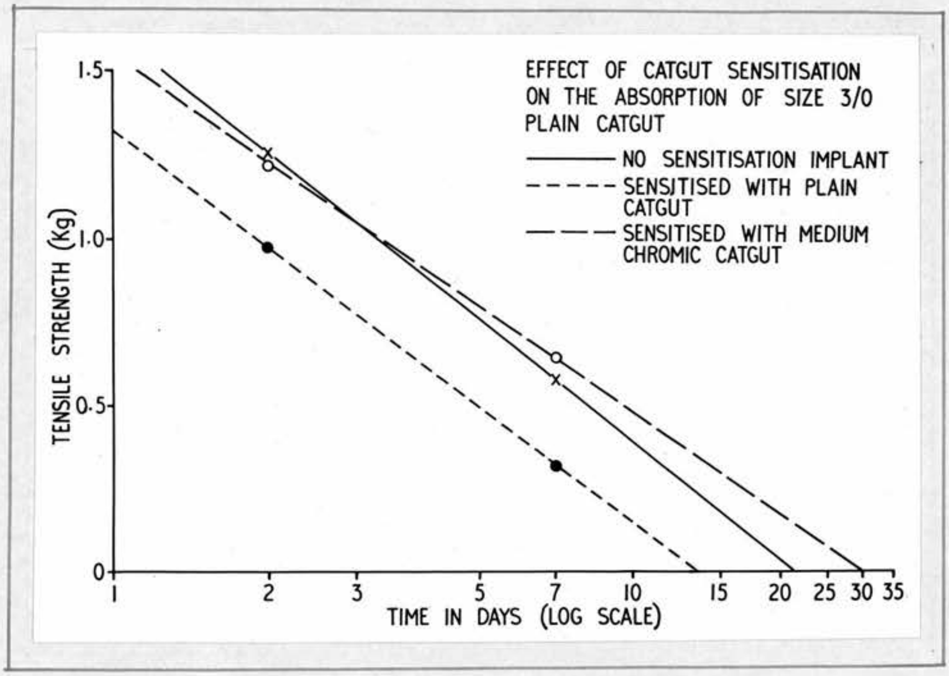

EFFECT OF CATGUT SENSITISATION ON THE ABSORPTION OF SIZE 3/0 PLAIN CATGUT
NO SENSITISATION IMPLANT
SENSITISED WITH PLAIN CATGUT
SENSITISED WITH MEDIUM CHROMIC CATGUT
TENSILE STRENGTH (Kg)
0
0.5
1.0
1.5
TIME IN DAYS (LOG SCALE)
1
2
3
5
7
10
15
20
25
30
35

Fig. 21

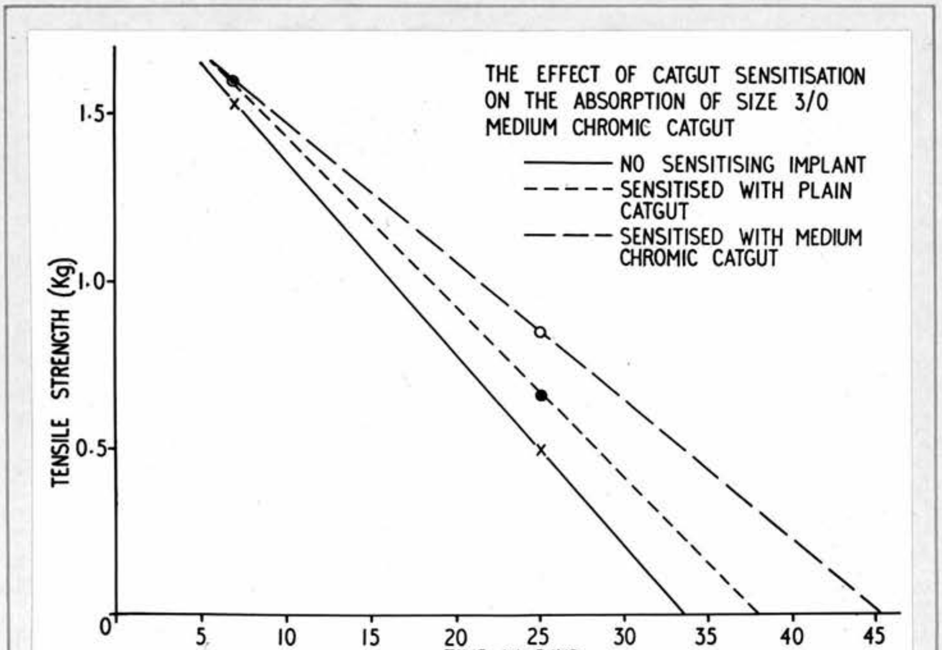

THE EFFECT OF CATGUT SENSITISATION ON THE ABSORPTION OF SIZE 3/0 MEDIUM CHROMIC CATGUT
NO SENSITISING IMPLANT
SENSITISED WITH PLAIN CATGUT
SENSITISED WITH MEDIUM CHROMIC CATGUT
TENSILE STRENGTH (Kg)
0
0.5
1.0
1.5
TIME IN DAYS
5
10
15
20
25
30
35
40
45

Fig. 22

The Effect of Alteration of Body Temperature

It seems logical to assume that the mechanism of absorption of surgical catgut is essentially an enzyme re-:action, for, even if the presence of living cells is shown to be necessary for the absorption process in vivo, it is difficult to conceive a purely mechanical process of dissolution of such a large foreign body as a catgut suture. If this is the case, in common with other enzyme reactions, the temperature at which the reaction takes place will play a major part in determining the velocity of the reaction.

Sizer (1945) implanted catgut and other collagenous sutures in the subcutaneous tissue of frogs and kept the frogs in baths of different temperature from 1.5°C. to 35°C. and found that absorption was more rapid at high temperatures than at low temperatures. No attempt was made to use a warm-blooded animal.

In the following experiments the body temperature of the rats was lowered by keeping the animals at a room temperature of about 15°C. after two subcutaneous injections daily of 5 mg. chlorpromazine hydrochloride. The response varied from animal to animal; one or two animals reached temperatures as low as 25°C., others only about 35°C. The average temperature throughout the experiments was about 30°C. i.e. a fall in temperature of 8°C.

Attempts to raise the body temperature by 3 or 4°C. by various methods (e.g. by injection of dinitrophenol, by injection of tetrahydro-β-naphthylamine, or by keeping the animals in an air temperature of 42°C. after injection of chlorpromazine) met with no success and it seemed impossible to keep a rat at a high temperature for more than an hour or two.

Table XI shows the results obtained from implants of plain 3/0 catgut in cooled rats and in normal rats.

TABLE XI - The effect of lowered body temperature on the absorption rate of catgut *in vivo*.

Body Temperature	Tensile Strength (Kg.)*	
	3 days	7 days
38°C. (Normal)	1.05	0.65
30°C.	1.35	1.14

*Each figure is the average of 40 determinations.

These results are shown in graphical form in fig. 23 (p. 62). The size 3/0 plain catgut implanted in the cooled rats showed a marked decrease in absorption rate which was significant at the 0.01 level.

The time taken for the tensile strength to be reduced to half its original value was increased from about 6 days to about 35 days.

In view of the difficulty and undesirability of keeping rats at lowered body temperature for prolonged

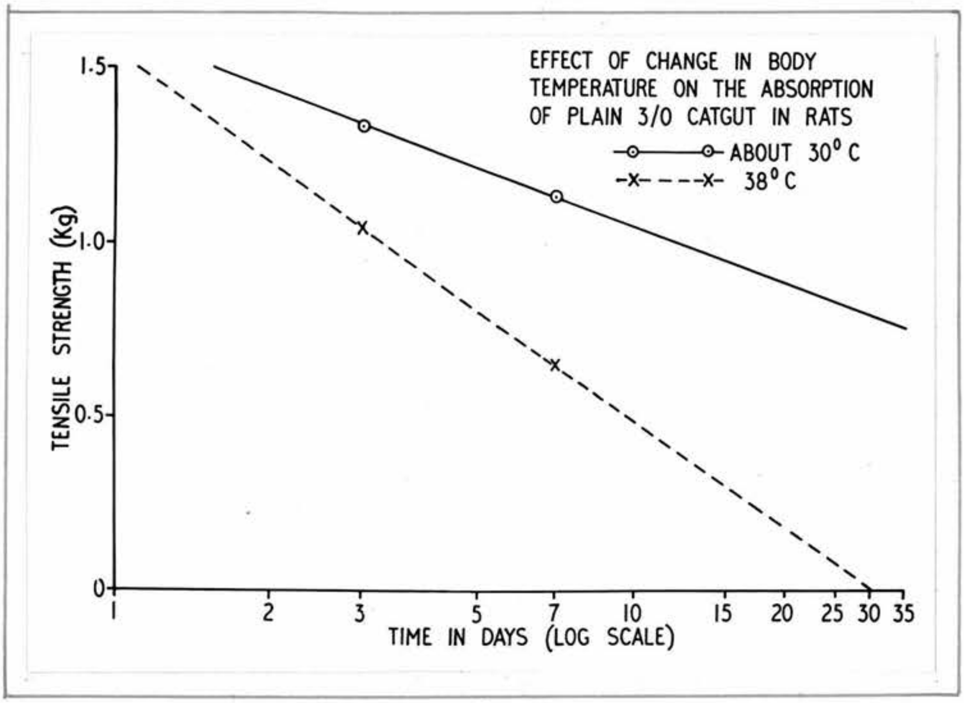

EFFECT OF CHANGE IN BODY TEMPERATURE ON THE ABSORPTION OF PLAIN 3/0 CATGUT IN RATS
ABOUT 30° C
38° C
TENSILE STRENGTH (Kg)
1.5
1.0
0.5
0
1
2
3
5
7
10
15
20
25
30
35
TIME IN DAYS (LOG SCALE)

Fig. 23

periods medium chromic catgut was not included in this study.

The Effect on the Tensile Strength of Catgut of Tissue Fluids Isolated from Tissue Cells

This experiment was designed to determine whether catgut is absorbed by tissue fluids in the absence of cellular elements.

The apparatus was designed so that the catgut was in close proximity to the cells but separated from them by a membrane which allowed fluids to pass through. The apparatus (fig. 24, p. 65) consisted of a chamber made from two "Perspex" rings, each supporting a diaphragm of "millipore" filter membrane. (Note: "Millipore" filter membrane has similar properties to that described by Goetz and Tseuneishi (1951) and is capable of retaining particles of 0.2 microns diameter on the surface. The technique of using such a membrane to make "diffusion chambers" to exclude tissue cells from implants in animals was devised by Algire (1953).)

The "Perspex" rings and diaphragms were sterilised by autoclaving at 15 lb./sq.in. steam pressure for 15 minutes. Four 3" lengths of plain catgut, size 3/0, were made into a coil about 10 mm. in diameter and placed in the cavity formed by cementing two rings together by means of a cellulose acetate cement. This formed a small chamber in which the catgut implant was isolated from the tissues themselves but which was permeable to tissue fluids.

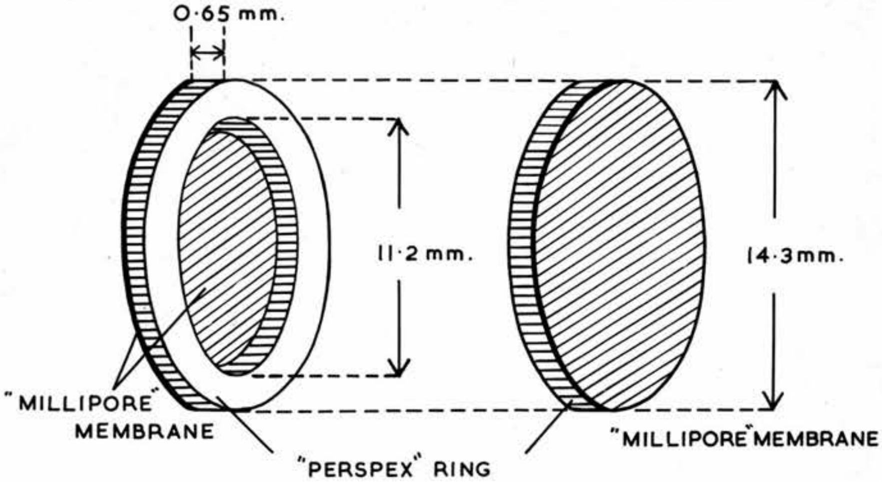
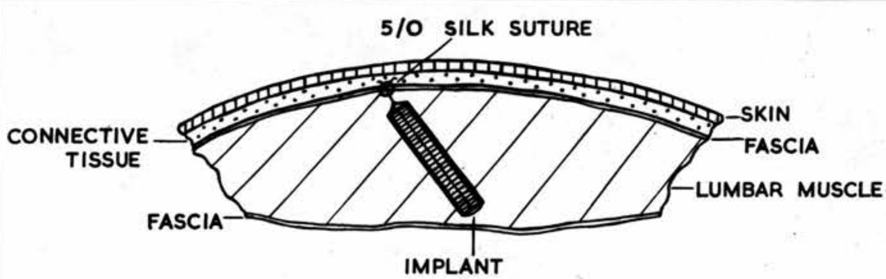


DIAGRAM OF CHAMBERS USED TO ISOLATE THE CATGUT IMPLANT FROM THE TISSUE CELLS.

Fig. 24



LONGITUDINAL SECTION SHOWING POSITION OF IMPLANT IN THE LUMBAR MUSCLE.

Fig. 25

"Control" chambers were made by substituting fine nylon mesh (33 meshes/cm.) for the "millipore" filter membrane.

One "control" chamber and one "millipore" chamber were implanted in each animal in the position shown in fig. 25 (p. 65) and fig. 26 (p. 67).

Five animals were used for each of the following survival periods - 2 days, 5 days, 10 days, 15 days and 25 days. After killing the animals, the implants were removed and the catgut tested for tensile strength.

Results

The "control" chambers were full of cellular material when opened, though this was readily stripped from the coil of catgut. The "millipore" chambers were entirely free from cellular material but were full of fluid. When tested for tensile strength the catgut from these implants yielded the results shown in Table XII.

TABLE XII - Tensile strength of plain catgut size 3/0 separated from the tissues *in vivo*.

Survival Period	"Control" Chambers Tensile Strength (Kg.)*	"Millipore" Chambers Tensile Strength (Kg.)*
2 days	1.20	1.51
5 days	0.66	1.21
10 days	0.25	0.96
15 days	0.04	0.61
25 days	0.00	0.00

*Each figure is the average of 20 determinations.

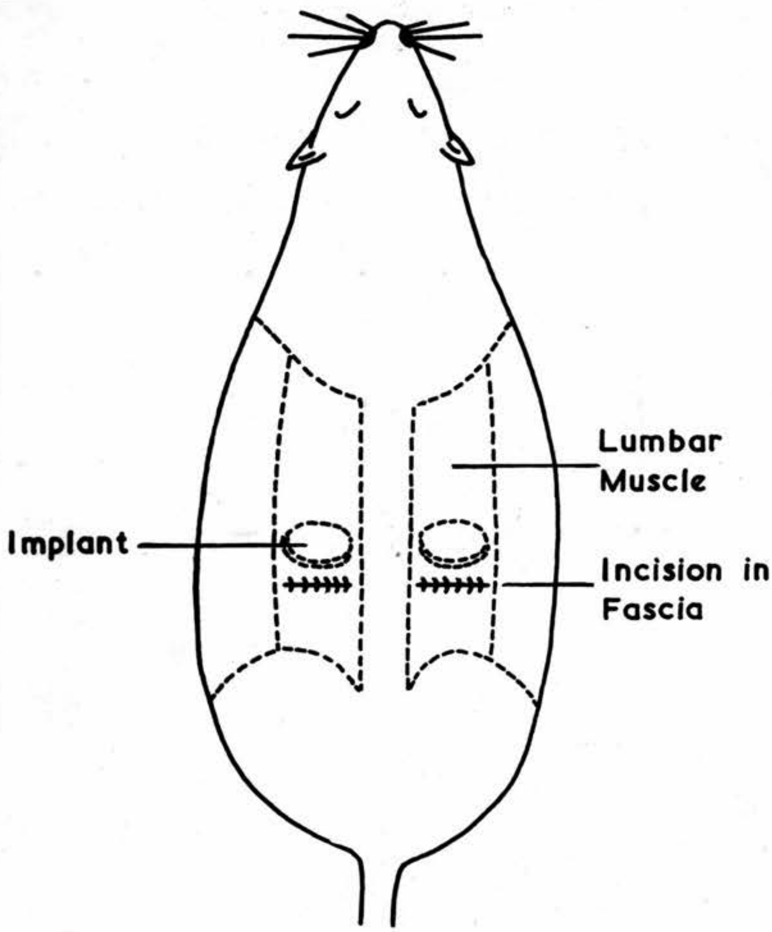


DIAGRAM SHOWING POSITION OF IMPLANT IN THE LUMBAR MUSCLE.

Fig. 26

These results are shown graphically in fig. 27 (p. 69). It can be seen that the fall in tensile strength of the "controls" followed the normal pattern very closely and the relationship between tensile strength and time was logarithmic in form. The behaviour of the catgut enclosed by "millipore" membrane was very different, being very similar to that of medium chromic catgut (fig. 12, p. 32).

It is clear that the proximity of living cells plays a major part in the absorption of catgut, but it is also clear that separation of the catgut from these cells does not completely stop the absorption process. The probable explanation of these two facts is that the enzymes responsible for lysis of the catgut are liberated in relatively high concentration from the cells and consequently when the catgut is in actual contact with the cells, absorption is rapid. When, however, the cells are separated from the catgut, the enzyme is rapidly diluted by tissue fluids and, probably, rapidly inactivated.

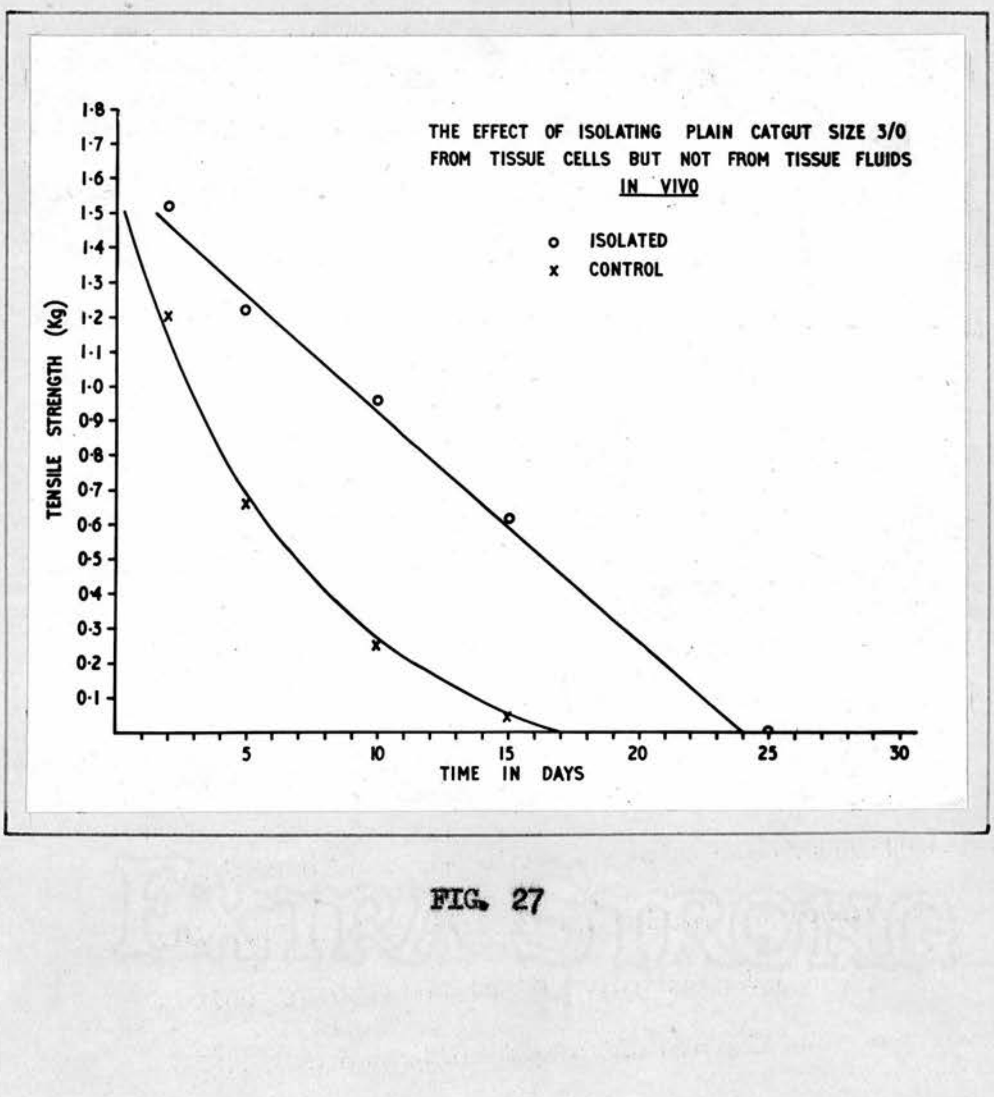

THE EFFECT OF ISOLATING PLAIN CATGUT SIZE 3/0
FROM TISSUE CELLS BUT NOT FROM TISSUE FLUIDS
IN VIVO
ISOLATED
CONTROL
TENSILE STRENGTH (Kg)
TIME IN DAYS
1·8
1·7
1·6
1·5
1·4
1·3
1·2
1·1
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
5
10
15
20
25
30

FIG. 27

HISTOLOGICAL FINDINGS

——— oOo ———

This section of work was limited to a comparison of the persistance of catgut substance in the muscle tissue and the loss of tensile strength and a comparison of the tissue reaction produced by plain and medium chromic catgut.

Experimental Method

The lumbar muscles were exposed as in the standard implantation method already described, and using a 10" length of catgut attached to an eyeless, 40 mm., round bodied needle a loop of catgut was implanted in each lumbar muscle, as in figs. 28 and 29 (p. 71) and the ends tied without tension.

After killing the animal with chloroform the muscle was carefully excised and the sectioning and staining procedure described in Appendix 5 carried out.

Results

The histological implants were done concurrently with the tensile strength implants described on pages 29 - 34. Figs. 30 to 34 (p. 72) and figs. 35 to 39 (p. 74) show photo-micrographs of some of the stages in the absorption of size 3/0 plain and medium chromic catgut.

In the case of plain catgut it can be seen from fig. 33 (p. 72) that after 25 days, when the tensile strength

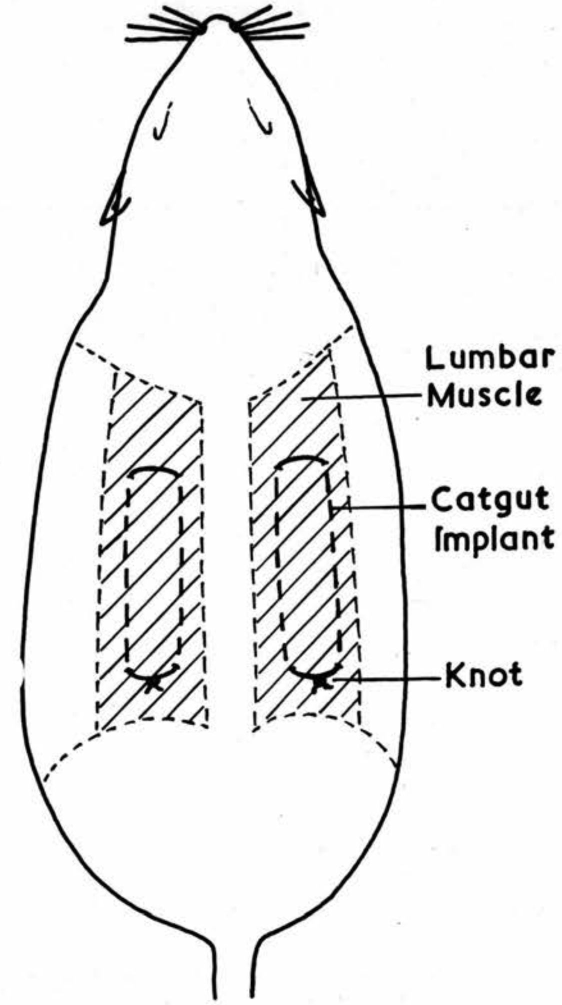
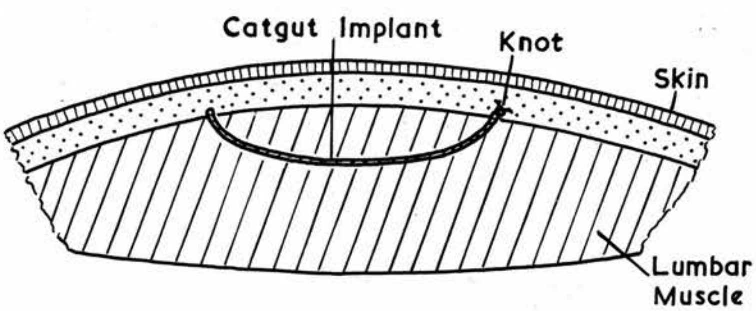


DIAGRAM SHOWING POSITION OF HISTOLOGICAL IMPLANTS

Fig. 28



LONGITUDINAL SECTION SHOWING POSITION OF HISTOLOGICAL IMPLANTS

Fig. 29

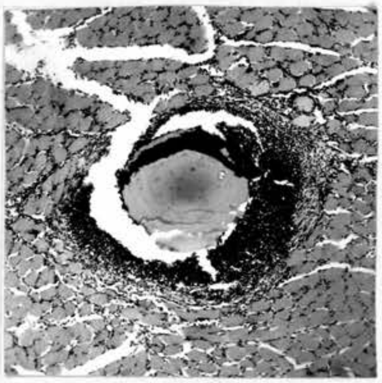


Fig. 30 - 3 days

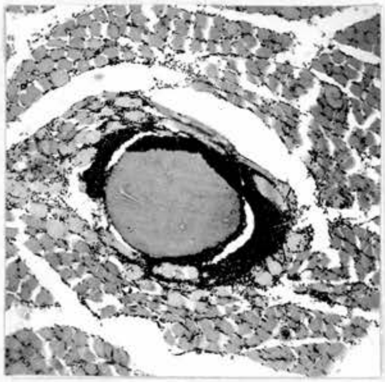


Fig. 31 - 7 days

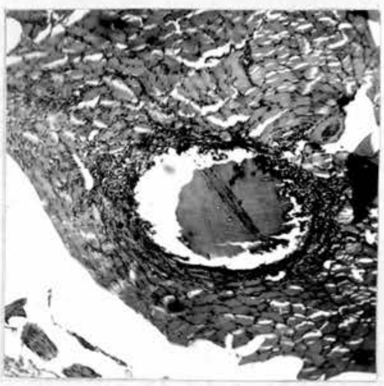


Fig. 32 - 15 days

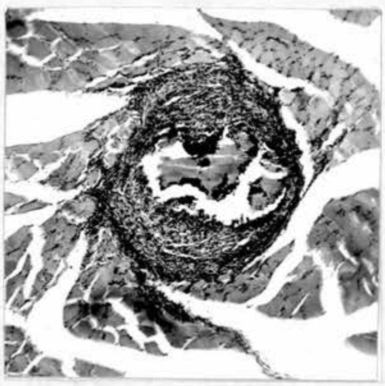


Fig. 33 - 25 days

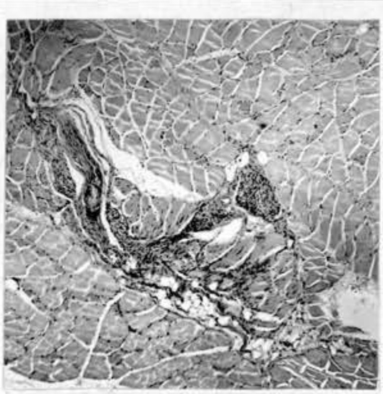


Fig. 34 - 30 days

Figs. 30-34: Absorption of Plain 3/0 Catgut in the lumbar muscle of Rats (x 50) has reached zero, the catgut has lost its integrity and is rapidly absorbed so that after 30 days there is no trace of catgut substance in the tissues. Size 5/0 plain catgut is completely absorbed in 20 days and sizes 0 and 2 are both almost completely absorbed in about 30 days, the increased bulk of catgut apparently making very little difference to the time taken for complete absorption.

In the case of medium chromic catgut, it can be seen from figs. 38 and 39 (p. 74) that catgut substance persists long after tensile strength has been reduced to zero and that even after 60 days, 25 days after reduction to zero strength, there are still particles of catgut remaining in the tissues. This was particularly evident with the thicker sizes of medium chromic catgut which, unlike plain catgut, persisted for considerably longer than the finer sizes in proportion to the bulk of catgut to be absorbed. In the case of size 2 medium chromic implants the outline of the cross section of catgut was still relatively circular after 40 days and there was still much catgut substance left after 70 days. This is in accordance with the findings of Jenkins <u>et al.</u> (1942) who observed that some types of chromic catgut were completely absorbed only after 3 to 6 months.

It can be seen that the tissue reaction produced by plain catgut is much greater than that produced by medium chromic catgut. This is particularly evident during the first seven days and confirms the findings of most other

Fig. 35 - 3 days

Fig. 36 - 7 days

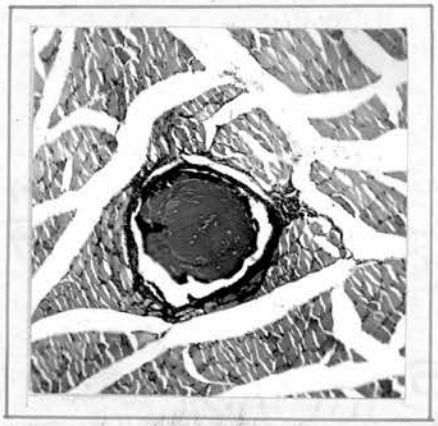


Fig. 37 - 30 days

Fig. 38 - 50 days

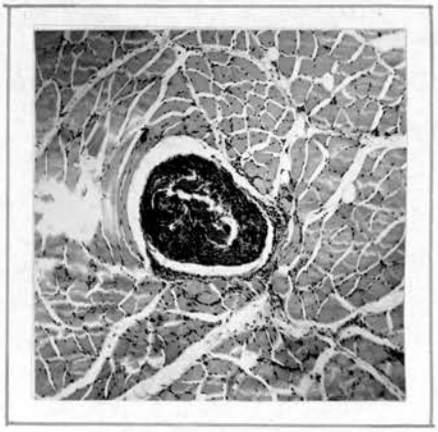


Fig. 39 - 60 days

Figs. 35-39: Absorption of Medium Chromic Size 3/0
Catgut in the lumbar muscle of Rats (x 50)

workers (e.g. Jenkins et al., 1942; Pickrell & Clay, 1944).

PART II

"IN VITRO" STUDIES

INTRODUCTION

Lister, as far back as 1881, (Lister, 1881), tested the tensile strength of catgut strands before and after steeping in serum at 98°F. for various times and found very little diminution in tensile strength. He also observed in surgical operations that where catgut was used as a drain, and consequently continually soaked with serum, there was never any sign of attack. Relating these two observations he came to the following conclusion: "The diminution (in tensile strength) is always absolutely limited to the parts within the tissues .... "This seems to me sufficient evidence that it is not a question of mere chemical solution of the catgut, but of disposal of the catgut in some way or other by the living textures."

Since then much work has been done on enzyme tests for catgut (Kraissl, 1934 and 1936; Jenkins *et al.*, 1942; Jenkins, 1942; Holder, 1946) but little work has been reported on the effect of serum and body fluids on the tensile strength of catgut.

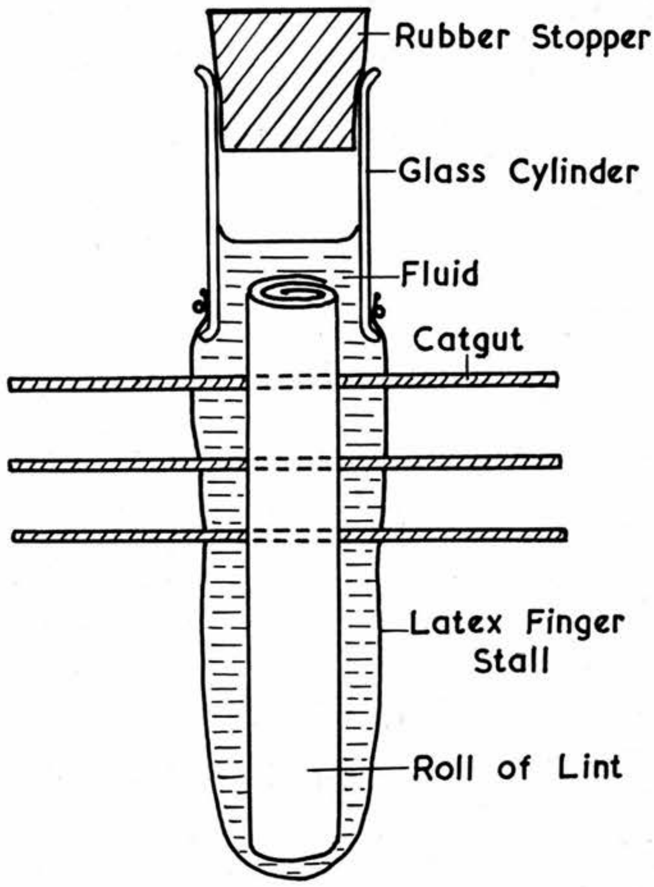
The action of the following fluids has, therefore, been investigated - normal saline, plasma, dextran solution and polyvinylpyrrolidone solution. These fluids are typical of the type of solution that would be encountered by catgut in normal use.

In addition, it is conceivable that catgut might also encounter certain enzymes such as streptokinase, hyaluronidase, pepsin and trypsin and the effect of these enzymes is also described.

DESCRIPTION OF TECHNIQUE

As in the *in vivo* studies the object was to devise a method of test which would give quantitative tensile strength measurements at various time intervals, as distinct from the method of Kraissl & Meleney (1934), and subsequent modifications, which records the time in which the tensile strength is reduced either to zero or to a definite value by the enzyme.

The apparatus evolved is shown in fig. 40 (p. 80) and consisted essentially of a latex finger stall attached to a glass cylinder. The catgut was passed through the latex finger stall and the roll of lint by means of an eyeless needle (40 mm. round bodied) and the fluid poured in through the glass cylinder which was then closed by a rubber stopper. The catgut strands (10 in each finger stall) were than tested for tensile strength without removing from the apparatus. Each unit contained about 15 ml. fluid. The whole apparatus could be sterilised before use, if necessary, by autoclaving and could be kept at any temperature desired by suspending by means of spring clips on a rack in an incubator.



APPARATUS FOR "IN VITRO" EXPERIMENTS

Fig. 40

THE EFFECT OF FLUIDS

——— oOo ———

The Effect of Normal Saline (0.9%)

These tests were done on size 3/0 plain and medium chromic catgut concurrently with the *in vivo* tests previously described. Table XIII summarises the effect of 0.9% sodium chloride on the tensile strength at various time intervals. The temperature was 37°C.

TABLE XIII - The effect of normal saline on the tensile strength of catgut *in vitro*.

Time (days)	Average Tensile Strength (Kg.)*	
	Plain	Medium Chromic
1	1.47	1.75
2	1.52	1.56
3	1.47	1.54
5	1.20	1.68
7	1.00	1.74
10	0.98	1.78
15	0.53	1.68
20	0.58	1.65
25	0.24	1.70
30	-	1.71

*Each figure represents the average of 40 determinations.

It is clear from these results that immersion in saline for up to 30 days has no effect on medium chromic catgut. In the case of plain catgut, however, tensile strength declined rapidly after 3 days and reached about 50%

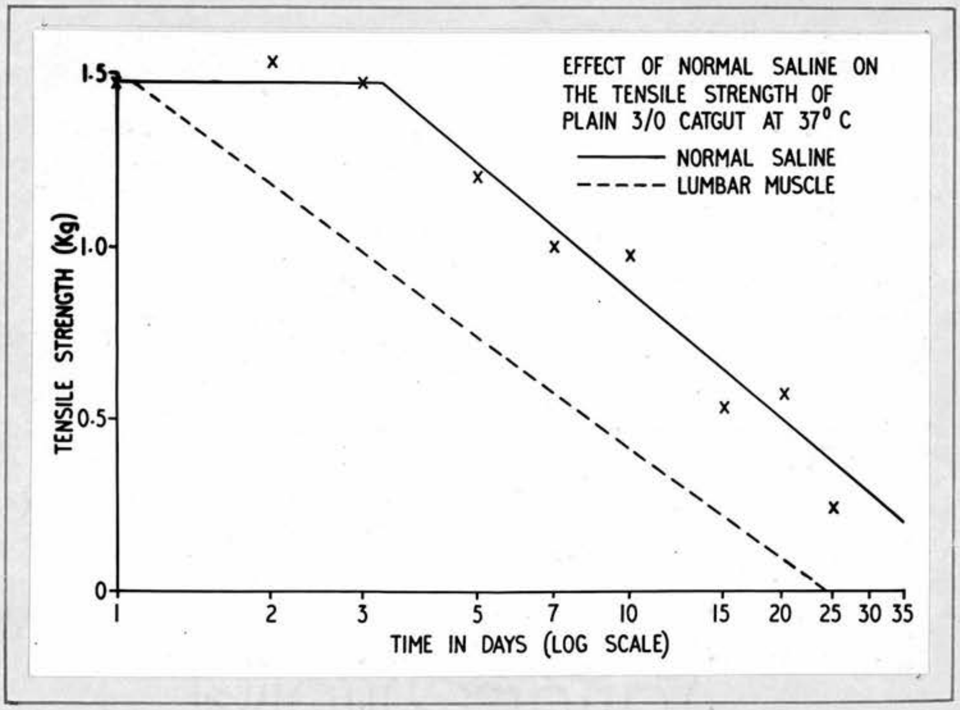

EFFECT OF NORMAL SALINE ON THE TENSILE STRENGTH OF PLAIN 3/0 CATGUT AT 37° C
NORMAL SALINE
LUMBAR MUSCLE
TENSILE STRENGTH (Kg)
1.5
1.0
0.5
0
1
2
3
5
7
10
15
20
25
30
35
TIME IN DAYS (LOG SCALE)

Fig. 41

of its original value in 15 days. Fig. 41 (p. 82) shows these tensile strength values plotted against the logarithm of the time and it can be seen that from about 3 days the tensile strength declines as the logarithm of the time.

This was rather an unexpected result and would appear to be a characteristic of plain catgut only. Medium chromic catgut was completely unaffected after 30 days. The possibility that the reduction in strength was due to bacterial action was considered and the experiment was checked by repeating the 10 days exposure to saline using sterilised saline and apparatus and using very careful aseptic technique in assembling. The results of the experiment are shown in Table XIV.

TABLE XIV - The effect of sterile normal saline.

Solution	Tensile Strength after Exposure for 10 days (Kg.)*
Non Sterile Saline	0.98
Sterile Saline	0.99
Non Sterile Saline + 0.002% Phenylmercuric nitrate	1.09

*Each figure is the average of 20 determinations.

It was deduced from these results that the loss in strength was not due to bacterial contamination.

It is probable that the loss in strength is due to excessive hydration of the catgut, the water molecules disrupting linkages between the collagen molecules. In the case of medium chromic catgut the chrome tanning process forms strong permanent links between the collagen molecules and these not only reduce the number of points at which hydration may occur but also resist any disruptive forces.

The Effect of Plasma

Plain catgut, size 3/0, was exposed to plasma (reconstituted freeze-dried) for 10 days at 37°C. and the tensile strength determined. Careful asepsis was observed in this experiment.

Result

Tensile strength after 10 days - 1.57 Kg. (Average of 20 determinations).

It can be seen that there is no loss of strength after 10 days in plasma. Hydration is probably prevented by the preferential attachment of water molecules to the hydrophilic proteins in plasma.

The Effect of Dextran and Polyvinylpyrrolidone Solutions

Dextran and polyvinylpyrrolidone are frequently used as plasma substitutes and their effect on the tensile strength of plain catgut, size 3/0, was also tested after 10 days exposure at 37°C.

Result

	Tensile Strength
Dextran	1.50 Kg.
Polyvinylpyrrolidone	1.20 Kg.

Each result is the average of 20 determinations.

The presence of hydrophilic colloids such as plasma proteins, dextran and to a lesser extent polyvinylpyrrolidone clearly tends to prevent loss of tensile strength of plain catgut by hydration.

THE EFFECT OF ENZYMES

——— oOo ———

The Effect of Streptokinase

Streptokinase (formerly known as fibrinolysin) is an enzyme isolated from cultures of a particular strain of Streptococcus and which has the property of causing rapid lysis of fibrin clots. It has been established that streptokinase is an activator of an enzyme precursor plasminogen which is a normal constituent of plasma (Christensen & MacLeod, 1945). The enzyme, plasmin, which is formed by this activation, is a potent fibrinolytic enzyme and it is conceivable that such an enzyme might also possess proteolytic activity against the collagen of catgut. The tensile strength of plain catgut, size 3/0, was, therefore, determined after exposure to solutions of streptokinase (4 Christensen units per ml.) in saline and in plasma. The results are shown in Table XV.

TABLE XV - The effect of streptokinase on the tensile strength of plain catgut size 3/0 *in vitro*.

Solution	Tensile Strength after 10 days at 37°C. (Kg.)*
Normal Saline	0.79
Normal Saline + Streptokinase	0.75
Plasma	1.46
Plasma + Streptokinase	1.63

*Each figure is the average of 20 determinations.

It is clear that no proteolytic action has taken place on the catgut. The plasminogen of fresh plasma was concentrated by a fractionation of the globulin, as described by Loomis _et al._ (1947). This fraction was also found to be inactive against catgut both by itself and when mixed with streptokinase. The streptokinase was active against fibrin when tested by the method of Permin (1950).

The Effect of Hyaluronidase

Hyaluronidase in saline solution having a concentration of 60 units (Benger) per ml. had no proteolytic action on plain catgut, size 3/0, as shown by the results in Table XVI.

TABLE XVI - The effect of hyaluronidase on the tensile strength of plain catgut size 3/0 *in vitro*.

Solution	Tensile Strength after 10 days at 37°C. (Kg.)*
Saline	0.79
Saline + 30 units/ml. Hyaluronidase	1.23
Saline + 60 units/ml. Hyaluronidase	1.32

*Each figure is the average of 20 determinations.

It is probable that the buffering action of the hyaluronidase and the presence of large colloidal protein molecules accounted for the increase in tensile strength.

The Effect of Pepsin and Trypsin

The proteolytic effect of pepsin and trypsin used as an in vitro test for the absorption properties of catgut has been adequately described by other workers (see page 77). Normally solutions of these enzymes very much more potent than those encountered in the stomach or duodenum are used in these in vitro tests (e.g. 10% pepsin) in order to make the test fairly rapid.

The only time that a suture would come into contact with these enzymes in use would be when it projects into the lumen of the stomach or duodenum and to estimate the potency of the enzyme solution at the very place and time at which it is secreted is obviously a very difficult thing to do as it is probably considerably diluted before it can be aspirated as gastric juice and tested for potency. Howes (1928) found that plain catgut projecting into the lumen of the stomach was reduced to zero strength in about 12 hours and chromic catgut in about 36 hours. Holder (1946) also found that plain, chromic and even iodine-sterilised catgut stitches projecting into the lumen of the stomach of rabbits were completely absorbed when examined four days post-operatively. Another problem, especially with trypsin, is the instability of aqueous solutions. Crystalline trypsin loses 75% of its activity in 3 hours at pH 7. The results in Table XVII were obtained using size 3/0 plain and medium chromic catgut with 1.0% solutions of the commercial enzymes at 37°C., the solutions being renewed twice daily.

Both plain and medium chromic catgut lose strength very rapidly, as would be expected, in 1.0% pepsin and trypsin, but in view of the difficulties mentioned above it is not possible to draw more than a qualitative conclusion.

TABLE XVII - The effect of pepsin and trypsin on the tensile strength of catgut size 3/0 *in vitro*.

Enzyme	Tensile Strength (Kg.)*			
	1 day		5 days	
	Plain	Medium Chromic	Plain	Medium Chromic
1.0% Pepsin pH 1.6	0.26	0.82	nil	nil
1.0% Trypsin pH 7.2	0.41	1.01	nil	0.27

*Each figure is the average of 20 determinations.

DISCUSSION

It would appear that this study is the first in which the precision of an in vivo test for the absorption of catgut has been determined. An accuracy of the order of $+2\frac{1}{2}$ & $-1\frac{1}{2}$ days for plain and $\pm$ 3 to 4 days for medium chromic catgut ($P = 0.95$) in measuring the absorption time has been obtained. Other workers (e.g. Jenkins, 1942; Holder, 1946) have emphasised the desirability of having pharmacopoeial standards for the absorption rate of surgical catgut and it seems that the technique evolved in these studies would form a satisfactory basis for such a standard test for absorb:ability. The technique is quick and relatively simple and involves no "major" surgery and the accuracy is as high as would be expected from a biological assay.

The concept of "The time taken for reduction to half the initial strength" as the absorption "end point" is one which is a distinct advance on the older concept of the time taken for reduction to zero strength since the suture would have little practical value in holding the wound once its strength had fallen below half its original value. The limitations of Holder's (1946) suggestion of an end-point of 450 g. is evident when one is dealing with fine sizes such as size 5/0 where the initial strength is only in the region of 450 - 500 g. It is suggested, therefore, that the time taken for the suture to be reduced to half its original "wet" tensile strength be regarded as the effective absorption time of surgical catgut.

The difference between plain and medium chromic gut manifests itself in three ways. Firstly, in the rate of absorption. Plain catgut loses strength rapidly in the first few days, and the curve of strength against time is of typical logarithmic shape in all sizes. Medium chromic catgut on the other hand loses virtually no strength in the first 3 to 5 days and thereafter loses strength slowly at more or less constant rate. This difference in behaviour is obviously of clinical significance and it may be seen readily that, in view of its rapid decline in strength in the first few days, plain catgut is safe to use only where rapid healing and minimal strain are assured. The "induction period" of about 5 days in the case of medium chromic catgut is obviously a safety factor during the period when the healing wound is at its weakest. Secondly, plain catgut evokes more tissue reaction than medium chromic catgut. This fact, of course, is not new and confirms the findings of most other workers. The difference is noticeable particularly in the first seven days after implantation and the advantage of using thin sizes of medium chromic catgut over using thick sizes of plain catgut is apparent. Thirdly, medium chromic catgut persists in the tissues after the suture has been reduced to below its effective strength for much longer than plain catgut. This is one of the least commendable features of medium chromic catgut but probably the least important clinically. There is obviously a need here for research on the part of manufacturers to produce a chromic type of catgut that will be rapidly absorbed after the strength has been reduced to below the strength of the wound.

With the exception of 5/0 plain catgut the diameter made very little difference to the time taken for the implants to reach zero strength. This is in agreement with the findings of Jenkins & Hrdina (1942a) who found that the finer sizes sometimes even outlasted the thicker sizes. It is here, however, that one's conception of what constitutes the "absorption time" of a catgut suture is important for, although a size 3/0 and a size 2 medium chromic catgut implant may both be reduced to 50% of their original strength in about 20 days, at the end of that 20 days the size 2 has an actual tensile strength of about 3.0 Kg. whereas size 3/0 only has a tensile strength of 0.83 Kg. Size 2 would reach a strength of 0.83 Kg. in about 30 days. It seems, therefore, contrary to the recommendations of Howes & Harvey (1929) and others, that there is some justification for the practice of using a thicker size of medium chromic catgut, even in relatively weak tissue, when it is intended that the suture shall last longer. Against the advantage of a longer time to reach the desired strength, however, it would be necessary to set the increased trauma to the tissue in using the thicker size and the increased bulk of tissue re-:action and the possibility of knot extrusion.

It is interesting to note that when the catgut passed through an incision the absorption rate was unaltered. One might have expected that the increase in blood supply and fibroblastic activity would have had an effect on the absorption rate.

The results obtained in the catgut sensitisation experiments were of considerable interest in view of the considerable divergence of opinion on this subject. The results of sensitisation with plain catgut followed the pattern described by other workers (e.g. Kraissl et al., 1938; Langston, 1942), plain catgut being absorbed with greater rapidity. Sensitising with plain catgut, however, had no significant effect on the absorption of medium chromic catgut. Sensitising with medium chromic catgut, however, causes delay in the absorption of medium chromic catgut and, again, no significant difference in the absorption rate of plain catgut. It must be borne in mind that related to body-weight very large quantities of catgut were used as sensitising implants; equivalent to about 1,500 ft. of catgut in the human subject.

Whatever the explanation or mechanism, however, the clinical significance is clear; namely, that catgut sensitisation is unlikely to be a factor in the disruption of surgical abdominal wounds since, when catgut is used, chromic catgut is almost exclusively the material of choice, plain catgut only being used in sites where rapid absorption is desirable.

Lowering of body temperature by 8°C. (14°F.), as would be expected, had a profound effect on the absorption rate and caused a slowing down of the absorption process almost amounting to a standstill. In view of the present emphasis on the use of hypothermia in surgery it is of significance to note that the absorption of catgut sutures is slowed down together with other metabolic processes.

It is unfortunate that it has not been possible to raise the body temperature in order to demonstrate a corresponding acceleration of absorption rate. If there is a significant increase in absorption rate under these circumstances, then post-operative fever is likely to be a serious complication where catgut has been used. Sizer (1945) demonstrated this increased absorption rate in frogs and found that a 7°C. increase in temperature led to a 100% increase in absorption rate. It is unlikely that a fever of the order of 7°C. (11°F.) would occur post-operatively and persist for any length of time but, assuming a compar:able effect in the human subject, a prolonged fever of 4°C. (7°F.) would have a very substantial effect on the absorption of catgut in a wound.

The <u>in vitro</u> studies served to emphasise the difference between plain and medium chromic catgut. It is perhaps not sufficiently realised that chromic catgut is not merely a slightly different sort of plain catgut but that it has fundamental differences in properties which make it almost a totally different suture material. It differs markedly in the tissue reaction it evokes; it differs in having a complete reversal of sensitising properties; it differs in retaining its strength almost unchanged at the time when plain catgut is losing strength most rapidly and the *in vitro* studies have shown its difference in suscept:ibility to the disruptive forces of hydration. The *in vitro* studies have also emphasised the difference in behaviour between plasma and normal saline which, although isotonic with plasma, behaves differently in its hydrating action on plain catgut. The presence of large hydrophilic molecules clearly affects the hydration of plain catgut.

It is of interest, too, that the finding that plasma causes virtually no loss in tensile strength even after many days' incubation at body temperature confirms the results which Lister obtained over seventy years ago (Lister, 1881).

The results obtained from the experiments on the effect of enzymes suffered from a certain degree of limitation. The streptokinase/plasminogen system and hyaluronidase appear to have no effect on the tensile strength of catgut. Pepsin and trypsin in 1.0% solution cause very rapid loss of tensile strength and emphasise that catgut sutures projecting into the lumen of the stomach or duodenum will be very rapidly digested.

The limitation of this _in vitro_ technique is, of course, that it is static whereas the absorption process in the living animal is dynamic. The body fluids are in continuous rapid circulation, fresh enzymes are being manufactured continually and are being freshly activated and, moreover, the enzymes are being produced by living cells in varying numbers in close proximity to the suture and there is no means of measuring the concentration and activity of the enzymes at the point of liberation.

This point is further emphasised by the experiment in which the catgut implants were isolated, _in vivo_, from the cells but not from the body fluids. The behaviour of plain catgut thus implanted was more akin to that of medium chromic catgut, the time for reduction to half the initial strength being about 13 days. Some of this delay in absorption would undoubtedly be due to the relatively slow diffusion rate of the fluids through the separating membrane and to the dilution of the proteolytic enzyme secreted by the cells, as it traverses the increased distance from the cell to the implant, but it is probable, too, that rapid inactivation of the enzyme also occurs.

It is worthy of note that when the _in vivo_ system itself becomes static, e.g. when cells and fluids are occluded in the space between the catgut and the walls of the polythene protector, then there is virtually no proteolytic action on the catgut. Under these conditions the life of the cells is probably short owing to difficulty of respiration and accumulation of metabolites.

It would be possible to adapt the _in vitro_ technique so that the fluids being tested were in continuous circulation and replacement but this would involve very large quantities of plasma and enzymes etc. and would tend to be more complicated and expensive than an _in vivo_ test!

The results of these studies and, particularly, of the _in vitro_ studies emphasise the point made by Mahoney (1943) that the problems of surgery and the suture are not purely mechanical problems, but problems involving delicate living cells.

SUMMARY

1. A technique for implanting surgical sutures in the tissues of animals has been devised whereby the changes in tensile strength of the suture material may be followed with a fair degree of accuracy and a suggestion has been made that the time taken for the average tensile strength of a suture to be reduced to half its original "wet" strength should be designated the "absorption time". The desir-:ability of standards for absorption rate has been emphasised.

2. The normal behaviour of plain and medium chromic catgut in rat muscle has been investigated and the difference in their behaviour demonstrated. The rate of loss of tensile strength of plain catgut follows a logarithmic curve whereas the loss of tensile strength of medium chromic catgut is negligible for the first 3 to 5 days and thereafter follows a linear relationship with time. The significance of this difference in surgical practice has been discussed.

3. The effect of the diameter of the surgical catgut on the absorption rate has been investigated. In the case of plain catgut there is a tendency from a tensile strength point of view for the finer sizes to be absorbed more quickly than the thicker sizes. In the case of medium chromic catgut the percentage

of the initial strength declines at substantially the same rate in all sizes.

4. By means of a statistical analysis the effects of the sex and body-weight of the animal have been shown to be of doubtful significance.
5. A transverse incision in the muscle through which the implant has been passed has been shown to have no significant effect on the absorption rate of either plain or medium chromic catgut.
6. When a rat has been sensitised by a previous implant of plain catgut, the absorption rate of subsequent plain catgut implants has been shown to be increased and when medium chromic catgut has been used as the sensitising implant, the absorption time of medium chromic has been shown to be prolonged.
7. The body temperature of the animal has been shown to have a very significant effect on the absorption rate of catgut. When the body temperature is lowered the catgut sutures are absorbed more slowly. The clinical significance of this in post-operative fever and hypothermic operations has been discussed.
8. Isolating the catgut implant from the body tissues but not from the body fluids had the effect of prolonging absorption considerably and the possible reasons for this have been discussed.
9. The absorption of catgut implants has also been

followed histologically, and the findings of other workers that plain catgut causes considerably more tissue reaction than medium chromic catgut and that, especially in the latter case, there is still much catgut material left when the strength has been reduced to zero are confirmed. Medium chromic catgut persists in the tissues for many weeks after reaching zero strength, whereas plain catgut is rapidly absorbed.

10. An <u>in vitro</u> technique has been developed for study-:ing the effect of fluids on the tensile strength of catgut and the effect of normal saline and various body fluids and enzymes has been studied.

11. Plain catgut has been shown to lose tensile strength rapidly in normal saline solution but not in plasma and to a lesser extent in dextran and polyvinyl-pyrrolidone solutions. Medium chromic catgut is unaffected by saline solution. The possible reasons for this are suggested.

12. The streptokinase/plasminogen system and hyaluronidase have been shown to have no action, <u>in vitro</u>, on the tensile strength of catgut.

13. Solutions of pepsin and trypsin of the order of con-centration found in the body have been shown to cause rapid loss in tensile strength of both plain and medium chromic catgut <u>in vitro</u>.

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APPENDIX 1

— oOo —

The Method of Sterilising Polythene Tubing

Sterilisation by autoclaving causes hardening and distortion of polythene, especially when in the form of thin-walled narrow tubing. Consequently a chemical method of sterilising was indicated. The following method was found to be satisfactory:-

a. Packing

The polythene implants were packed in lots of 10 in glass suture tubes about 9 mm. in diameter.

b. Sterilising

The tubes were then filled with the following solution and allowed to stand for 24 hours:-

Solution of Formaldehyde B.P. . 4 ml.
Cetrimide B.P. .... 0.01 g.
Alcohol .... 70 ml.
Water to .... 100 ml.

c. Removal of Formaldehyde

The sterilising solution was decanted off and the tubes filled with the following solution and allowed to stand for 24 hours:-

Removal of Formaldehyde (contd.)

Hydrogen Peroxide 100 vols. ... 10 ml.

Alcohol .... 70 ml.

Water to .... 100 ml.

d. Rinsing

The hydrogen peroxide solution was decanted off and the polythene rinsed with sterile 95% alcohol (filtered through a Seitz filter) three times.

e. Drying

The tubes were placed under a vacuum bell-jar and subjected to a vacuum of about 74 cm. of Hg until dry.

Samples taken from polythene processed by this method were always shown to be sterile and free from formaldehyde. The tubes were hermetically sealed by fusion of the glass for storage.

APPENDIX 2

— oOo —

Physical Methods of Testing Catgut

Diameter

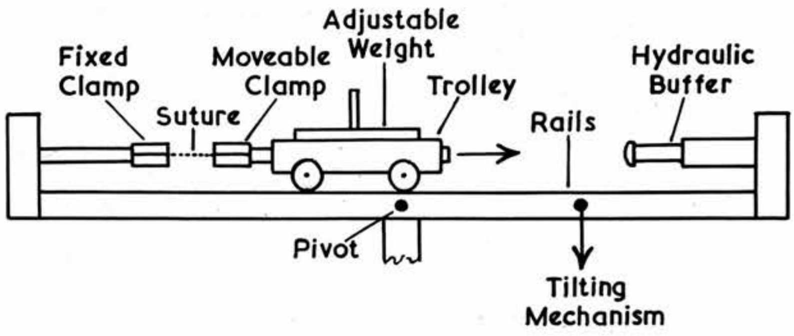
The diameter of the catgut was measured by means of a dial-reading micrometer graduated in half thousandths of an inch and exerting a pressure on the catgut of 7 ozs. in accordance with the specification laid down in the British Pharmacopoeia (1953) p. 129.

Tensile Strength

a. The Instrument

The instrument used was the inclined plane tensiometer specified by the United States Pharmacopoeia XIV (1950) p. 765. This instrument consists of a fixed clamp and clamp attached to a weighted trolley running on rails. A recording device is attached to the trolley (fig. 42, p. 108). In operation the rails are tilted mechanically at a constant rate. As the angle of tilt increases the load applied to the suture increases and the breaking point is automatically recorded. The advantages of this type of machine over the pendulum type specified by the British Pharmacopoeia are:

(i) There is a constant rate of application of load irrespective of the stretch of



DIAGRAMATIC REPRESENTATION OF THE INCLINED PLANE TENSIOMETER

Fig. 42

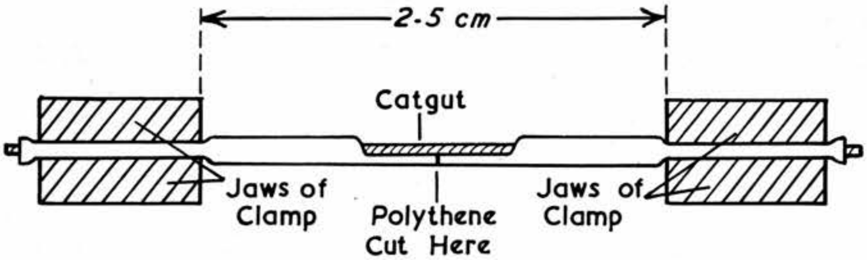


DIAGRAM SHOWING METHOD OF TESTING TENSILE STRENGTH

Fig. 43

the material under test.

(ii) The recording scale is linear.

b. Testing the Implants

The distance between the jaws of the two clamps was adjusted to 2.5 cm. and the implant clamped firmly as shown in fig. 43 (p. 108).

The narrow strip of polythene adjacent to the exposed length of suture was cut carefully with a pair of sharp pointed scissors.

The tensile strength was then measured in the normal way.

APPENDIX 3

— oOo —

Chemical Methods of Testing Catgut

Chromium Content

The method used was substantially that described by Davies & Innes (1944) for chrome leather and consisted of a "wet oxidation" by perchloric acid followed by titration of the liberated chromic acid with ferrous ammonium sulphate.

a. Oxidation

About 0.1 g. catgut was weighed into a 150 ml. flat bottomed "Pyrex" flask and the following mixture added:-

Perchloric acid (60%) .... 10 ml.

Nitric acid (conc.) .... 5 ml.

Sulphuric acid (conc.) .... 5 ml.

The flask was heated on an electric hot plate until the mixture turned from pale green to orange, when it was boiled for a further 5 minutes.

The flask was then removed from the hot plate and cooled rapidly in cold water and 50 ml. cold distilled water added rapidly.

After boiling for 15 minutes to drive off any free chlorine the contents were allowed to cool.

b. Titration

The contents of the flask were then

Titration (contd.)

titrated against 0.02N ferrous ammonium sulphate using o-phenanthroline as indicator and the chromium content calculated in terms of Cr_2O_3.

Resistance to Papain Solution

a. Apparatus

The method adopted was substantially that of Kraissl (1934) in which a loop of catgut was immersed in the enzyme solution under 20 g. tension. The breaking time was automatically recorded by an electric clock mechanism. The tubes containing the enzyme solution were kept at constant temperature by immersion in a thermostat bath at 37°C. (± 0.1°C.).

b. Enzyme Solution

The enzyme solution used was a 3% papain solution activated with sodium bisulphite in a phosphate/borate buffer at pH 7.2 standardised so that 0.04 ml. diluted to 1 ml. liberates 2.5 mg. of tyrosine from 5 ml. of 2% casein solution at 37°C. after 15 minutes.

APPENDIX 4

— oOo —

Statistical Methods Used in the Studies

Precision of Method

The accuracy of the 50% absorption time measurement was determined by first calculating the standard deviation of the average tensile strength measurement for that particular time. The range to include 19 out of 20 such measurements was then calculated (S.D. x 1.96) and the range of time corresponding to this range estimated from the appropriate graph. In the case of plain catgut the values on either side of the average value were different due to the shape of the curve. In the case of medium chromic catgut the average value was in the centre of the range since the curve was a straight line at that point.

Sex and Body-Weight

In order to make use of all the observations together in testing the significance of sex and body-weight, multiple regression equations were calculated for plain and medium chromic catgut. In the case of plain catgut, body-weight, logarithm of time and diameter were taken as independent variables and tensile strength as the dependent variable and in the case of medium chromic catgut, body-weight, time, diameter and time squared were taken as independent variables and tensile strength as the dependent variable. The calculations incorporating the test of significance for body-weight were then made according to the method described by Woolf (1951).

The sex effect was tested for significance by a variance ratio test when the observations were classified into separate sex groups.

Effect of an Incision

The effect of an incision on plain catgut was test:ed for significance by comparing the slope of the two log. lines using the "t" test (Davies, 1949). As reported in the text, the two sets of tensile strength measurements for medium chromic catgut, when expressed graphically, showed an even closer approximation than the plain catgut observations and, therefore, a significance test was deemed unnecessary.

Sensitisation and Body Temperature Effects

On the suggestion of Dr. Woolf, the "two point" method, already referred to in the text, was used for these comparisons. For this purpose the alternative linear equation for plain 3/0 catgut was calculated, expressing tensile strength in terms of the logarithm of the time. The two point comparisons were tested against this by variance ratio. The "control" observations for medium chromic catgut differed significantly from the original curve and the results from sensitised animals were compared with the "control" line by variance ratio.

The difference between the results from "cooled" and "control" animals was so obviously larger than that which had already been proved significant in the sensitising experiments that there was no need for a test of significance.

APPENDIX 5

— oOo —

Histological Methods Used

After killing the animal with chloroform, the lumbar muscle was excised and fixed in 10% neutral formol-saline for 24 hours. A suitable sized piece of muscle containing the implant was dehydrated by passing through 50%, 70% and two changes of 100% Dioxan for at least 2 hours in each change. The tissue was then placed in a mixture of equal parts of paraffin wax (M.P. 58°C.) and Dioxan at 40°C. for 2 hours and thence to three changes of paraffin wax at 60°C. (2 hours in each change).

After blocking out in the usual way, sections were cut at 10 microns and floated out on albuminised slides and dried.

The staining technique was as follows:-

a. Xylol .... 5 mins.

b. Absolute Alcohol .... 2 mins.

c. 50% Alcohol .... 5 mins.

d. Weigert's Haematoxylin .... 15 mins.

e. Ehrlich's Haematoxylin .... 5 mins.

f. Rinse - tap water

g. Acid Alcohol .... <u>ca</u> 10 secs.

h. Rinse and "Blue" in tap water .. 5 mins.

i. Van Gieson's stain .... 3 mins.

j. Rinse in tap water

k. Absolute Alcohol .... 5 mins.

l. Xylol .... 5 mins.

m. Mount in "DePeX" mountant.

This staining technique gave very good contrast between the catgut implant and the surrounding tissue and stained as follows:-

Catgut and collagen fibres .... bright red

Muscle fibres .... yellowish brown

Nuclei .... brownish black

Erythrocytes .... yellow

APPENDIX 6

— oOo —

A Protocol of a Single Experiment

Experiment 2

The Absorption Behaviour of Plain and Medium Chromic Catgut

NOTE: This experiment is summarised on pp. 29 - 34.

a. Purpose

To study the normal behaviour of plain and medium chromic catgut (size 3/0) *in vivo* as demonstrated by the relationship between the tensile strength of the catgut and the time.

b. Method

The standard procedure developed in Experiment 1 was used for implanting the catgut in the lumbar muscles of rats. Five rats were used for each survival period (i.e. 20 tensile strength measurements) and the following survival periods used:-

Plain catgut (3/0): 1, 2, 3, 5, 7, 10 and 15 days.

Medium chromic catgut (3/0): 1, 2, 3, 5, 7, 10, 15, 20, 25 and 30 days.

c. Operating Programme

(i) Plain Catgut Size 3/0

Rat Nos.	Date Implanted	Date Killed	Survival Period (days)
13 - 15	21.7.51	23.7.51	2
19 - 21	24.7.51	25.7.51	1

(i) Plain Catgut Size 3/0 (contd.)

Rat Nos.	Date Implanted	Date Killed	Survival Period (days)
25 - 27	28. 7.51	31. 7.51	3
31 - 33	31. 7.51	5. 8.51	5
37 - 39	11. 8.51	26. 8.51	15
43 - 45	14. 8.51	21. 8.51	7
49 - 51	18. 8.51	28. 8.51	10
55 - 56	21. 8.51	22. 8.51	1
61 - 62	25. 8.51	27. 8.51	2
67 - 68	28. 8.51	12. 9.51	15
73 - 74	8. 9.51	18. 9.51	10
79 - 80	11. 9.51	16. 9.51	5
85 - 86	18. 9.51	25. 9.51	7
91 - 92	22. 9.51	25. 9.51	3

(ii) Medium Chromic Catgut Size 3/0

Rat Nos.	Date Implanted	Date Killed	Survival Period (days)
97 - 99	25. 9.51	20.10.51	25
103 - 105	29. 9.51	29.10.51	30
109 - 111	2.10.51	22.10.51	20
115 - 117	6.10.51	21.10.51	15
121 - 123	9.10.51	16.10.51	7
127 - 129	13.10.51	23.10.51	10
133 - 135	20.10.51	23.10.51	3
139 - 141	23.10.51	28.10.51	5
145 - 147	27.10.51	29.10.51	2
151 - 153	30.10.51	31.10.51	1
157 - 158	6.11.51	1.12.51	25
163 - 164	10.11.51	10.12.51	30
169 - 170	13.11.51	3.12.51	20
175 - 176	17.11.51	2.12.51	15
181 - 182	20.11.51	25.11.51	5
187 - 188	24.11.51	4.12.51	10
193 - 194	1.12.51	3.12.51	2
199 - 200	3.12.51	10.12.51	7
205 - 206	8.12.51	11.12.51	3
211 - 212	10.12.51	11.12.51	1

NOTE: This experiment was performed concurrently with the experiment involving incised muscle (pp. 50 - 53) and also with the experiments involving histological implants (pp. 70 - 75). For one survival period (e.g. 2 days) 3 rats (nos. 13 - 15) were used for this experiment, 2 rats (nos. 16 - 17) were used for the incised muscle experiment and 1 rat (no. 18) for a histological implant. Later 2 rats (nos. 61 - 62), 3 rats (nos. 63 - 65) and 1 rat (no. 66) were used respectively for the above experiments making a total of 5 rats for the implants in intact muscle, 5 rats for the implants in incised muscle and 2 rats for the histological implants. This procedure was designed to nullify any variations in the strain of rat used throughout the experiments.

d. Results

After killing the animals and removing the implants according to the procedure specified in the standard technique described on pp. 24 - 28 the catgut was tested for tensile strength (see Appendix 2) and the results in the following tables obtained.

The "initial strength" of the catgut was defined as the strength after soaking in plasma for 24 hours according to the technique described on pp. 79 and 80.

NOTE: In the following tables the headings for the columns are replaced by the letters A, B, C and R in order to simplify the lay-out.

A = Tensile strength of implant in Kg.

B = Body-weight of rat.

C = Sex of rat.

R = Rat number.

Where "D" appears in column "A" it signifies either that the animal died before the survival period was complet:ed or that the implant was damaged in removal.

(i) <u>Plain Catgut Size 3/0</u>

1 day			
A	B	C	R
1.16 1.18 1.54 1.95	160	m	19
1.39 1.47 1.47 1.51	150	m	20
1.20 1.31 1.99 1.66	160	m	21
1.87 1.41 1.64 1.14	160	m	55
1.62 1.20 1.56 1.27	160	m	56
1.48 - Average			

2 days			
A	B	C	R
1.25 1.35 1.45 1.51	180	m	13
0.62 1.29 1.35 1.76	180	m	14
1.41 1.43 0.52 0.29	170	m	15
1.56 0.98 0.83 0.75	150	f	61
1.43 1.12 1.06 0.98	150	f	62
1.15 - Average			

3 days			
A	B	C	R
0.89 1.08 1.16 1.27	140	m	25
0.73 1.04 1.54 1.60	130	m	26
0.54 1.43 1.02 0.66	140	m	27
0.39 0.46 0.66 1.85	230	m	91
0.95 1.08 0.91 2.08	180	f	92
1.07 - Average			

5 days			
A	B	C	R
1.51 1.20 0.58 0.23	160	m	31
1.02 0.75 0.66 0.61	150	m	32
0.33 0.71 0.54 1.04	180	m	33
0.27 0.37 1.25 0.33	160	m	79
0.79 0.77 0.75 1.25	170	f	80
0.75 - Average			

(i) Plain Catgut Size 3/0 (contd.)

7 days			
A	B	C	R
0.00 0.00 0.20 0.70	160	f	43
0.03 0.07 0.13 0.33	180	m	44
0.22 0.83 0.48 1.06	170	f	45
0.39 0.15 0.75 0.33	140	f	85
1.18 1.25 0.73 0.15	200	m	86
0.45 - Average			

10 days			
A	B	C	R
0.12 0.20 0.06 0.73	150	f	49
0.75 0.25 0.10 0.00	140	f	50
0.21 0.00 0.93 0.39	160	f	51
0.00 0.15 0.48 0.19	170	m	73
1.04 0.64 1.25 1.66	150	f	74
0.46 - Average			

15 days			
A	B	C	R
0.00 0.00 0.91 0.00	160	f	37
0.00 0.00 0.91 0.00	160	f	38
0.91 0.00 D D	160	f	39
0.00 0.37 0.13 0.12	200	m	67
0.35 0.91 0.11 0.09	140	m	68
0.27 - Average			

(ii) Medium Chromic Catgut Size 3/0

1 day			
A	B	C	R
2.12 2.03 1.78 1.49	150	m	151
2.08 1.99 1.66 1.62	160	m	152
1.87 1.29 1.41 1.91	180	m	153
2.15 2.32 1.83 1.83	180	f	211
1.91 1.99 1.91 1.91	160	m	212
1.86 - Average			

2 days			
A	B	C	R
1.66 1.87 1.41 0.95	180	m	145
2.12 1.25 1.45 1.70	160	m	146
1.25 1.87 1.62 1.87	170	m	147
1.95 1.91 1.70 1.45	130	f	193
1.16 1.58 1.08 1.54	120	f	194
1.57 - Average			

3 days			
A	B	C	R
1.37 1.66 1.87 1.49	220	m	133
2.03 1.99 1.41 1.41	150	f	134
1.66 1.33 1.45 1.58	250	f	135
1.33 1.41 1.54 1.99	110	f	205
1.49 1.70 1.91 1.62	150	m	206
1.61 - Average			

5 days			
A	B	C	R
1.70 1.95 1.41 1.74	130	f	139
2.12 1.62 1.37 1.16	190	f	140
1.83 1.66 1.37 1.99	280	m	141
1.54 1.58 1.70 2.12	140	m	181
1.20 1.16 2.08 1.91	120	m	182
1.66 - Average			

(ii) Medium Chromic Catgut Size 3/0

7 days			
A	B	C	R
1.70 1.66 1.58 1.27	190	m	121
1.89 2.08 1.70 1.89	210	m	122
1.54 1.33 1.99 1.16	170	f	123
0.91 0.42 1.12 1.54	170	m	199
1.00 1.62 1.41 1.87	180	m	200
1.48 - Average			

10 days			
A	B	C	R
1.66 1.93 1.76 1.60	170	f	127
0.62 1.91 1.64 1.25	250	m	128
1.49 1.64 1.45 1.27	250	m	129
1.45 1.27 1.74 1.60	230	m	187
1.87 1.41 1.00 0.95	130	f	188
1.48 - Average			

15 days			
A	B	C	R
1.64 1.29 1.39 0.98	240	m	115
1.14 1.08 1.54 1.45	280	m	116
1.72 1.41 0.91 1.47	190	f	117
0.58 1.04 1.47 0.77	210	m	175
0.91 1.58 1.06 0.62	180	m	176
1.20 - Average			

20 days			
A	B	C	R
1.51 1.35 1.29 0.48	210	m	109
0.56 0.91 0.79 0.29	240	m	110
0.68 1.06 1.29 0.54	220	m	111
0.95 0.68 1.49 1.31	220	m	169
0.64 0.64 0.50 0.50	230	m	170
0.87 - Average			

(ii) Medium Chromic Catgut Size 3/0 (contd.)

25 days				30 days			
A	B	C	R	A	B	C	R
0.37 0.42 0.33 0.29	170	f	97	0.12 0.12 0.00 0.00	280	m	103
0.71 0.83 0.27 0.10	210	m	98	0.23 0.00 0.00 0.00	260	m	104
1.20 0.60 0.17 0.75	170	f	99	0.00 0.00 0.35 0.19	300	m	105
0.35 0.12 0.58 0.52	210	m	157	0.00 0.84 0.91 0.67	190	m	163
0.00 0.62 0.10 0.42	220	m	158	0.09 0.52 0.00 0.00	220	m	164
0.44 - Average				0.20 - Average			

Initial Strengths of Plain and Medium Chromic

Catgut Size 3/0

Tensile Strengths (Kg.)	
Plain 3/0	Medium Chromic 3/0
1.39	1.81
1.43	1.76
1.51	2.10
1.47	1.55
1.16	1.89
1.76	1.39
1.39	1.30
1.47	0.97
1.47	1.64
1.87	2.10
1.81	2.02
1.56	1.85
1.60	1.89
1.41	1.72
1.14	1.43
1.27	1.43
1.29	1.64
1.58	1.30
1.37	1.60
1.58	1.76
1.48	1.66

The results in these foregoing tables may be summarised in the following table (Table II in the text p. 30).

"Loss in strength in vivo of plain and medium chromic catgut, size 3/0

Time (days)	Plain Catgut		Medium Chromic Catgut	
	Tens. Str. (Kg.)	% Init. Str.	Tens. Str. (Kg.)	% Init. Str.
1	1.48	100	1.86	112
2	1.15	78	1.57	95
3	1.07	72	1.61	98
5	0.75	51	1.66	100
7	0.45	30	1.48	89
10	0.46	31	1.48	89
15	0.27	18	1.20	73
20	-	-	0.87	53
25	-	-	0.44	27
30	-	-	0.20	12
	Init. Str. 1.48 Kg.		Init. Str. 1.66 Kg.	

These average tensile strengths were plotted against the logarithm of the time in the case of plain catgut and against the time in the case of medium chromic catgut (figs. 44 and 45). The points on the first graph (plain catgut, fig. 44) show a good approximation to a straight line and the "best straight line" was fitted to these points by the method of least squares.

In the case of the second graph (medium chromic catgut, fig. 45) there was obviously little change in strength until after the 5th day, but from 5 to 30 days the points showed a reasonable approximation to a straight line. The "best straight line" was, therefore, calculated for the points at 5, 7, 10, 15, 20, 25 and 30 days.

e. Calculation of the "best straight line"

When Y = Log. time (plain) or time (medium chromic)

X = Av. tensile strength (Kg.)

N = Number of observations

m = Tangent of the angle of slope of the line

and c = Zero intercept

$$\text{then } m = \frac{N\Sigma XY - \Sigma X.\Sigma Y}{N\Sigma X^2 - (\Sigma X)^2} \quad \text{.......} \quad (1)$$

$$\text{and } c = \frac{\Sigma Y - m\Sigma X}{N} \quad \text{.......} \quad (2)$$

$$\text{and } Y = mX + c \quad \text{.......} \quad (3)$$

Taking two arbitrary values for X in equation (3), the corresponding values of Y may be calculated and through these two points the "best straight line" may be drawn (see figs. 44 and 45).

(i) Plain Catgut Size 3/0

N = 6 (since log. 1 = 0 the observation for 1 day is omitted)

Time (days)	Log. Time
2	0.301
3	0.477
5	0.699
7	0.845
10	1.000
15	1.176

ΣY	4.498
ΣX	4.150
ΣXY	2.539
$\Sigma X.\Sigma Y$	18.667
$(\Sigma X)^2$	17.223
ΣX^2	3.517

(i) <u>Plain Catgut Size 3/0 (contd.)</u>

$$m = \frac{6 \times 2.539 - 18.667}{6 \times 3.517 - 17.223} \quad \ldots\ldots\ldots\ldots \quad (1)$$

$$= -0.887$$

$$c = \frac{4.498 + 0.887 \times 4.15}{6} \quad \ldots\ldots\ldots \quad (2)$$

$$= 1.363$$

When $X = 1.40$ Kg.

then $Y = -0.887 \times 1.400 + 1.363$ .... (3)

Y = log. of time = 0.121 or 1.3 days

When $X = 0.10$ Kg.

then $Y = -0.887 \times 0.100 + 1.363$ .... (3)

Y = log. of time = 1.274 or 18.8 days

These two points were inserted in fig. 44 and the straight line drawn through them.

(ii) <u>Medium Chromic Catgut Size 3/0</u>

$N = 7$ (from 5 - 30 days)

ΣY	112.00
ΣX	7.33
ΣXY	85.86
$\Sigma X . \Sigma Y$	820.96
$(\Sigma X)^2$	53.73
ΣX^2	9.57

$$m = \frac{7 \times 85.86 - 820.96}{7 \times 7.33 - 53.73} \quad \ldots\ldots\ldots\ldots \quad (1)$$

$$= -16.61$$

$$c = \frac{112.00 + 16.61 \times 7.33}{7} \quad \ldots\ldots\ldots \quad (2)$$

$$= 33.39$$

(ii) Medium Chromic Catgut Size 3/0 (contd.)

When $X = 1.5$ Kg.

then $Y = -16.61 \times 1.500 + 33.39$ .... (3)

$= 8.47$ days

When $X = 0.1$ Kg.

then $Y = -16.61 \times 0.100 + 33.39$ .... (3)

$= 31.73$ days

These two points were inserted in fig. 45 and the straight line drawn through them.

f. Conclusions

(i) Plain Catgut

The tensile strength of size 3/0 plain catgut declined in direct proportion to the logarithm of the time when implanted in the lumbar muscle of rats. The strength was reduced to 50% of the initial strength in approximately 5 days.

(ii) Medium Chromic Catgut

The tensile strength of size 3/0 medium chromic catgut showed virtually no change for about 5 days and thereafter declined in almost direct proportion to the time. The strength was reduced to 50% of the initial strength in approximately 20 days.

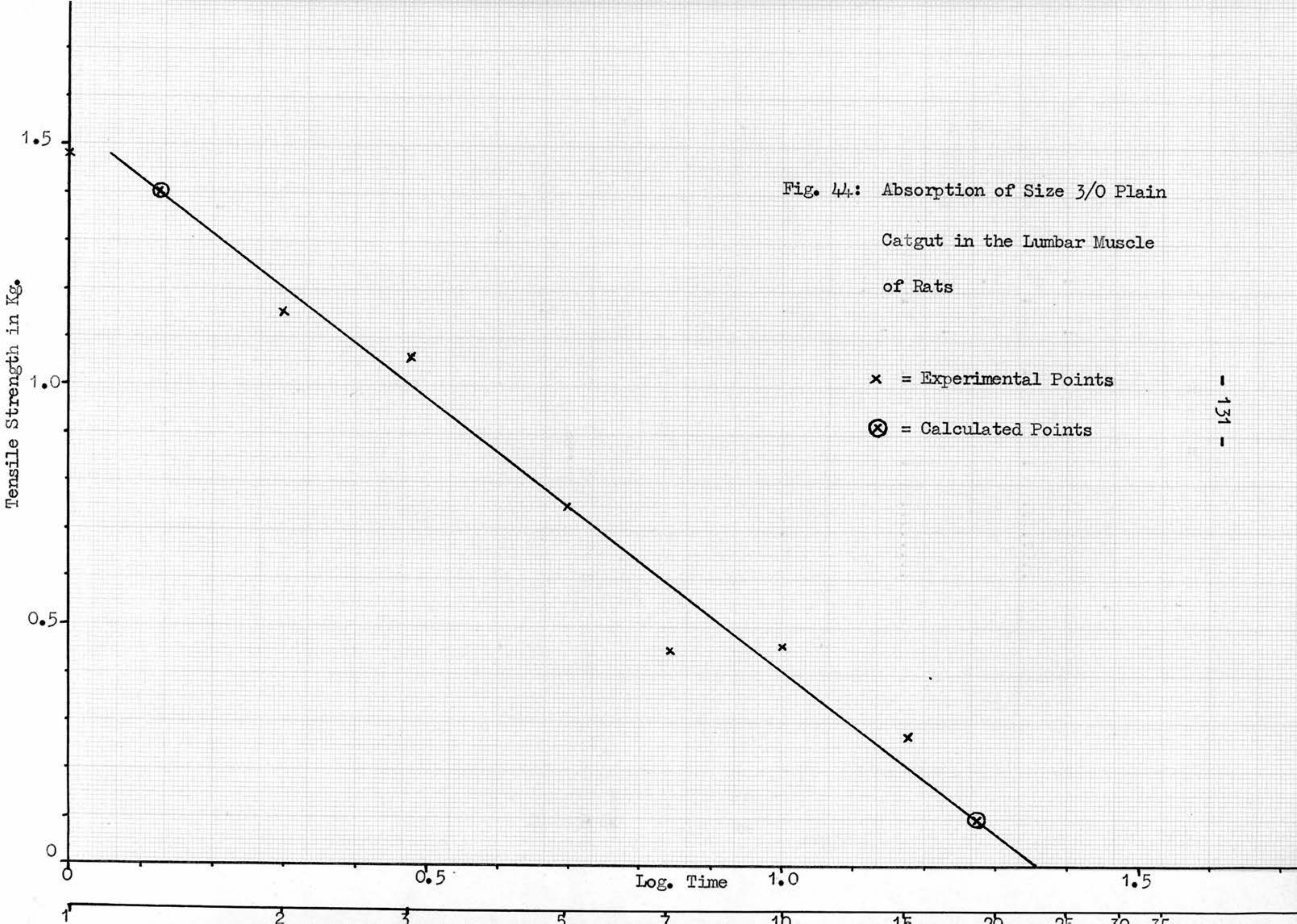


Fig. 44: Absorption of Size 3/0 Plain Catgut in the Lumbar Muscle of Rats

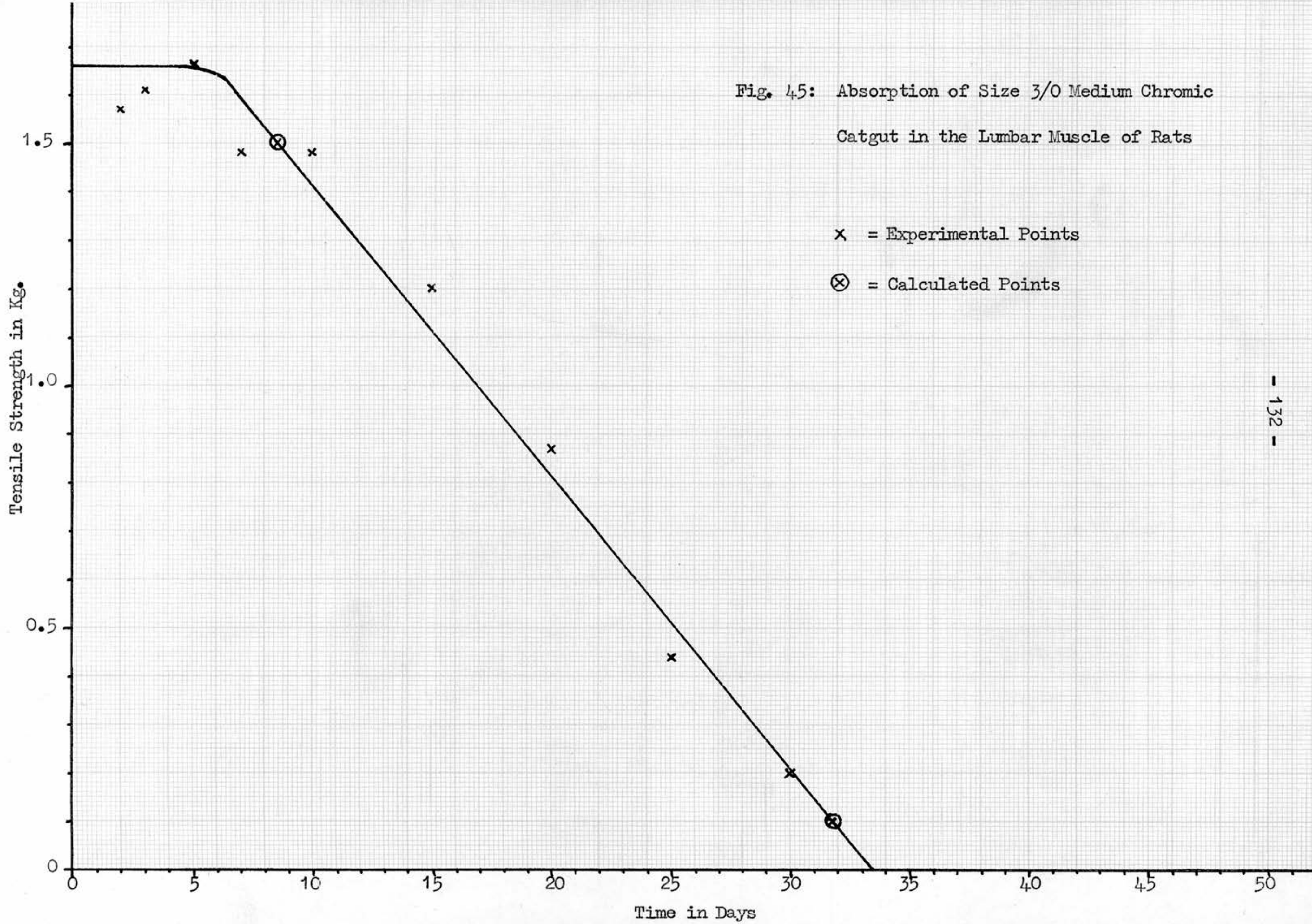


Fig. 45: Absorption of Size 3/0 Medium Chromic Catgut in the Lumbar Muscle of Rats

APPENDIX 7

— oOo —

Detailed Experimental Data

The tables in this appendix contain the complete data from which the average figures in the tables in the text were calculated.

In order to simplify the lay-out of the tables the following abbreviations are used for the column headings:

A = Tensile strength of implant in Kg.

B = Body-weight of rat.

C = Sex of rat

Where the letter "D" appears in column "A" it signifies either that the animal died before the completion of the survival period or that the implant was damaged during removal from the animal.

In the cases of Table II (p. 30), Table IV (p. 36), Table V (p. 37), Table VIII (p. 53) and Table IX (p. 56) the data for the normal absorption of size 3/0 plain and medium chromic catgut have already been tabulated in Appendix 6 (pp. 117 to 132).

Data Summarised in Table IV

Plain Catgut Size 5/0

1 day		
A	B	C
0.69 0.67 0.52 0.43	240	f
0.46 0.52 0.46 0.42	220	f
0.59 0.42 0.44 0.37	240	f
0.57 0.54 0.54 0.42	240	f
0.62 0.54 0.30 0.50	220	f
0.50 - Average		

2 days		
A	B	C
0.16 0.27 0.25 0.30	400	m
0.31 0.21 0.21 0.56	330	m
0.17 0.40 D D	300	m
0.30 0.58 0.29 0.24	330	m
0.33 0.44 0.49 0.53	340	m
0.34 - Average		

3 days		
A	B	C
0.00 0.02 0.11 0.47	380	m
0.54 0.29 0.22 0.00	290	m
0.45 0.07 0.56 0.25	370	m
0.34 0.42 0.28 0.41	330	m
0.30 0.67 0.16 0.29	400	m
0.29 - Average		

5 days		
A	B	C
0.17 0.11 0.09 0.05	230	f
0.00 0.00 0.06 0.06	220	f
0.03 0.25 0.02 0.04	210	f
0.03 0.03 0.20 0.20	230	f
0.15 0.04 0.38 0.35	250	f
0.11 - Average		

Plain Catgut Size 5/0 (contd.)

7 days		
A	B	C
0.00 0.00 0.00 0.00	250	f
0.49 0.09 0.02 0.25	270	f
0.28 0.26 0.00 0.04	220	f
0.03 0.39 0.37 0.03	210	f
0.04 0.00 0.00 0.00	240	f
0.11 - Average		

10 days		
A	B	C
0.00 0.00 0.00 0.29	250	f
0.00 0.09 0.42 0.15	230	f
0.00 0.02 0.00 0.11	200	f
0.00 0.00 0.18 0.05	230	f
0.00 0.00 0.18 0.18	230	f
0.08 - Average		

15 days		
A	B	C
0.00 0.00 0.02 0.17	240	f
0.00 0.00 0.00 0.05	250	f
0.00 0.00 0.00 0.00	270	f
0.00 0.00 0.00 0.05	270	f
0.00 0.00 0.00 0.09	240	f
0.02 - Average		

Data Summarised in Table IV

Plain Catgut Size 0

1 day		
A	B	C
4.32 4.32 3.73 3.65	200	m
4.15 4.23 3.53 4.03	210	m
3.53 3.82 3.57 3.94	220	m
3.44 3.15 4.23 3.73	210	m
4.03 3.61 3.73 3.98	210	m
3.84 - Average		

2 days		
A	B	C
3.82 4.23 3.57 3.82	230	f
3.69 3.65 3.53 3.32	240	f
3.69 4.03 3.07 3.32	220	f
4.23 3.90 3.32 3.28	220	f
4.15 2.66 3.57 3.20	250	f
3.60 - Average		

3 days		
A	B	C
3.90 4.03 3.90 3.65	250	f
2.49 2.41 3.03 1.95	280	f
1.95 2.41 3.49 3.32	230	f
3.57 3.32 3.49 2.41	300	m
3.78 2.65 4.15 3.65	380	m
3.23 - Average		

5 days		
A	B	C
2.45 2.41 0.91 1.58	230	m
3.11 2.61 3.69 3.44	240	m
1.95 4.03 2.74 2.49	200	m
0.87 1.83 0.71 0.50	230	m
1.99 2.99 3.69 2.07	230	m
2.30 - Average		

Plain Catgut Size 0 (contd.)

7 days		
A	B	C
2.49 2.08 0.87 2.70	330	f
3.11 3.28 2.16 3.40	270	f
1.79 2.57 2.03 2.16	250	f
1.66 1.49 1.58 2.57	250	f
0.87 0.58 1.41 3.49	270	f
2.11 - Average		

10 days		
A	B	C
0.21 2.90 0.21 2.41	240	m
2.86 2.95 3.32 1.49	220	m
2.08 1.16 3.11 1.95	230	m
1.91 2.74 2.20 1.20	240	m
2.78 1.08 4.15 0.41	210	m
2.06 - Average		

15 days		
A	B	C
0.00 0.00 0.08 0.23	210	f
1.97 1.78 1.68 2.07	250	f
D D 0.00 0.00	230	f
0.17 1.08 0.46 1.68	300	f
0.71 0.79 1.14 0.25	200	f
0.78 - Average		

20 days		
A	B	C
0.00 0.00 0.58 0.66	280	f
0.25 1.99 1.24 1.10	260	f
0.00 0.41 0.44 1.18	260	f
0.00 0.00 0.64 0.62	260	f
0.00 0.00 0.00 0.00	250	f
0.46 - Average		

Plain Catgut Size 0 (contd.)

25 days		
A	B	C
0.00 0.00 0.00 0.00	280	f
0.00 0.19 0.11 0.46	290	m
0.00 0.10 0.00 0.00	300	m
0.00 0.00 0.00 0.00	290	m
0.00 0.00 0.00 0.00	220	f
0.04 - Average		

Data Summarised in Table IV

Plain Catgut Size 2

1 day		
A	B	C
4.94 5.73 5.93 3.81	270	m
5.23 4.52 5.48 4.23	280	m
5.15 5.06 5.19 4.90	230	m
4.86 4.94 4.57 5.94	280	m
4.73 5.56 5.19 5.35	280	m
5.07 - Average		

2 days		
A	B	C
4.48 5.06 4.90 4.48	240	m
3.50 5.23 4.57 4.73	230	m
6.23 5.48 4.40 4.98	220	m
5.40 5.73 3.74 4.48	250	m
6.56 5.06 4.57 4.90	230	m
4.92 - Average		

3 days		
A	B	C
4.44 4.52 4.39 3.23	190	f
3.65 4.60 1.99 4.15	250	f
4.23 4.89 4.06 3.90	240	f
4.10 4.44 4.81 4.89	210	f
4.23 4.15 3.61 4.73	270	f
4.15 - Average		

5 days		
A	B	C
1.66 3.24 5.23 4.56	250	m
6.22 4.86 5.48 4.86	260	m
3.82 1.16 4.56 3.40	210	m
4.32 2.90 3.98 5.15	250	m
4.56 3.32 3.24 3.32	200	m
3.99 - Average		

Plain Catgut Size 2 (contd.)

7 days		
A	B	C
3.82 3.94 3.53 2.74	270	f
2.37 2.61 0.83 0.08	240	f
5.89 4.07 1.04 1.91	240	f
2.70 1.87 3.07 2.82	260	f
2.74 0.75 3.65 1.00	210	f
2.57 - Average		

10 days		
A	B	C
2.57 2.53 1.66 0.79	270	f
0.46 2.24 2.07 0.46	250	f
2.53 3.98 2.70 3.44	200	f
1.79 2.12 1.41 1.00	300	f
2.12 2.49 0.42 0.00	230	f
1.84 - Average		

15 days		
A	B	C
0.25 0.29 0.00 0.00	200	f
1.00 1.00 0.00 0.00	230	f
0.21 0.71 0.00 0.00	300	f
0.17 0.21 0.00 0.00	250	f
2.03 0.75 0.00 0.00	280	f
0.33 - Average		

20 days		
A	B	C
1.22 0.21 0.00 0.00	370	m
0.00 0.00 0.00 0.00	250	m
1.87 0.50 0.66 0.12	250	m
1.60 0.89 1.18 0.00	270	m
0.79 0.44 0.31 0.35	280	m
0.51 - Average		

Plain Catgut Size 2 (contd.)

25 days		
A	B	C
0.00 0.00 0.00 0.00	290	m
0.00 0.00 0.00 0.00	270	m
0.00 0.00 0.00 0.00	300	m
0.00 0.00 0.00 0.00	250	m
0.00 0.00 0.00 0.00	250	m
0.00 - Average		

Initial Strengths of Plain Catgut

Size 5/0	Size 3/0	Size 0	Size 2
0.58	1.39	3.47	5.27
0.47	1.43	3.96	6.07
0.40	1.51	3.59	4.54
0.53	1.47	4.10	4.19
0.27	1.16	4.35	4.39
0.44	1.76	3.41	5.74
0.60	1.39	3.33	4.85
0.57	1.47	3.89	4.99
0.54	1.47	3.95	5.09
0.54	1.87	3.74	5.06
0.58	1.81	3.84	4.93
0.44	1.56	3.52	5.75
0.52	1.60	4.21	5.17
0.51	1.41	4.28	5.11
0.41	1.14	3.72	5.58
0.55	1.27	3.85	5.72
0.47	1.29	4.54	4.83
0.61	1.58	3.79	4.62
0.51	1.37	4.15	4.79
0.54	1.58	3.14	5.39
0.50	1.48	3.84	5.10

Data Summarised in Table V

Medium Chromic Catgut Size 5/0

1 day		
A	B	C
0.44 0.44 0.65 0.27	290	m
0.53 0.49 0.39 0.53	340	m
0.48 0.30 0.25 0.35	310	f
0.30 0.56 0.32 0.36	300	m
0.48 0.48 0.30 0.59	230	m
0.43 - Average		

2 days		
A	B	C
0.56 0.44 0.44 0.47	180	m
0.41 0.40 0.39 0.59	180	m
0.60 0.52 0.53 0.57	220	m
0.52 0.35 0.55 0.39	230	m
0.74 0.55 0.42 0.50	250	m
0.50 - Average		

3 days		
A	B	C
0.45 0.27 0.49 0.52	250	m
0.26 0.24 0.47 0.52	250	m
0.27 0.21 0.44 0.46	250	m
0.38 0.40 0.26 0.35	190	m
0.43 0.42 0.33 0.50	260	m
0.38 - Average		

5 days		
A	B	C
0.56 0.53 0.60 0.61	200	m
0.53 0.40 0.35 0.63	180	m
0.50 0.54 0.21 0.33	200	m
0.32 0.28 0.44 0.54	220	m
0.51 0.41 0.54 0.40	210	m
0.46 - Average		

Medium Chromic Catgut Size 5/0 (contd.)

7 days		
A	B	C
0.35 0.35 0.32 0.31	220	m
0.38 0.41 0.34 0.30	220	m
0.62 0.45 0.38 0.27	270	m
0.37 0.41 0.31 0.29	190	m
0.38 0.37 0.37 0.34	200	m
0.37 - Average		

10 days		
A	B	C
0.47 0.28 0.33 0.43	230	m
0.29 0.57 0.23 0.16	230	m
0.57 0.41 0.44 0.48	250	m
0.32 0.44 0.43 0.50	280	m
D D D D	-	-
0.40 - Average		

15 days		
A	B	C
0.15 0.25 0.04 0.35	250	m
0.21 0.23 0.42 0.00	240	m
0.23 0.14 0.39 0.36	280	m
0.04 0.45 0.30 0.00	250	m
0.47 0.24 0.13 0.42	230	m
0.24 - Average		

20 days		
A	B	C
0.28 0.42 0.31 0.19	280	m
0.45 0.34 0.34 0.29	250	m
0.12 0.34 0.22 D	230	m
0.29 0.31 0.40 0.29	250	m
0.34 0.31 D D	240	m
0.31 - Average		

Medium Chromic Catgut Size 5/0 (contd.)

25 days			30 days		
A	B	C	A	B	C
0.13 0.16 0.42 0.14	250	m	0.11 0.17 0.08 0.00	220	m
0.20 0.30 0.09 0.00	230	m	0.06 0.20 0.00 0.00	250	m
0.04 0.05 0.04 D	230	m	0.24 0.26 0.00 0.00	210	m
0.11 0.15 0.00 0.00	270	m	0.29 0.00 0.00 0.00	280	m
0.04 0.07 0.00 0.00	210	m	0.22 0.13 0.00 0.00	290	m
0.10 - Average			0.09 - Average		

Data Summarised in Table V

Medium Chromic Catgut Size O

1 day		
A	B	C
3.98 5.15 3.90 3.74	230	f
3.82 3.24 3.40 4.86	200	f
4.07 3.53 3.15 3.82	160	f
4.11 3.57 4.32 3.90	180	f
3.32 3.32 3.03 4.15	180	f
3.82 - Average		

2 days		
A	B	C
3.74 2.99 3.24 4.40	170	f
3.78 3.82 4.28 3.82	180	f
2.82 3.57 2.62 3.28	190	f
3.82 3.74 3.57 3.65	160	f
3.65 2.82 3.32 4.07	190	f
3.55 - Average		

3 days		
A	B	C
3.90 3.82 3.15 3.69	250	m
3.74 4.32 3.07 3.40	300	m
3.28 3.98 3.98 3.65	230	m
4.07 3.90 3.24 2.57	290	m
3.98 3.03 3.69 3.15	180	m
3.58 - Average		

5 days		
A	B	C
2.62 2.70 2.45 3.32	300	m
3.49 2.99 2.82 2.45	180	f
3.53 3.11 3.11 3.32	280	m
3.57 2.91 3.57 3.40	210	f
3.94 3.03 2.82 2.08	210	f
3.06 - Average		

Medium Chromic Catgut Size 0 (contd.)

7 days		
A	B	C
3.32 2.95 4.15 3.53	210	f
3.86 3.40 2.74 2.99	180	f
3.82 3.28 3.98 1.87	180	f
4.15 3.11 3.24 3.32	170	f
3.53 3.53 3.28 3.15	160	f
3.36 - Average		

10 days		
A	B	C
0.58 3.86 3.86 3.69	260	f
3.15 2.66 2.99 3.28	280	f
3.86 1.70 3.32 3.11	280	f
3.90 2.24 3.53 3.98	220	m
3.28 2.20 2.99 3.07	270	m
3.06 - Average		

15 days		
A	B	C
1.41 1.79 1.83 3.44	210	f
1.37 1.66 2.74 2.16	200	f
2.12 1.66 2.08 1.24	230	f
1.58 1.45 1.04 1.79	210	f
1.37 0.62 2.41 2.24	210	f
1.80 - Average		

20 days		
A	B	C
0.46 0.66 0.83 0.87	210	f
0.50 1.58 1.12 1.58	190	f
1.08 2.08 1.41 1.45	210	f
0.79 1.41 1.66 2.28	200	f
0.96 1.16 0.37 0.79	180	f
1.15 - Average		

Medium Chromic Catgut Size 0 (contd.)

25 days		
A	B	C
2.08 0.96 0.96 1.62	290	m
0.50 0.33 0.25 1.33	250	f
2.20 0.42 0.71 1.12	260	f
1.45 0.21 0.50 0.87	280	f
D D D D	-	-
0.97 - Average		

30 days		
A	B	C
0.10 0.15 0.21 0.00	300	m
0.13 0.12 0.93 0.00	270	m
0.00 0.00 0.00 0.00	220	m
0.35 0.00 0.00 0.00	330	m
0.00 0.00 0.00 0.00	230	m
0.10 - Average		

35 days		
A	B	C
0.00 0.00 0.00 0.00	250	m
0.00 0.00 0.00 0.00	280	m
0.00 0.00 0.00 0.15	260	m
0.00 0.00 0.00 0.23	360	m
0.00 0.00 0.00 0.00	230	f
0.02 - Average		

40 days		
A	B	C
0.00 0.00 0.00 0.00	300	m
0.00 0.00 0.00 0.00	320	m
0.00 0.00 0.14 1.25	330	m
0.00 0.00 0.09 1.25	280	m
0.00 0.00 0.00 0.00	290	m
0.14 - Average		

Data Summarised in Table V

Medium Chromic Catgut Size 2

1 day		
A	B	C
6.06 6.77 6.39 5.44	330	m
5.56 5.31 6.39 5.85	300	m
6.27 6.18 6.10 5.52	250	m
5.85 5.48 7.64 6.23	250	m
5.52 5.60 5.81 6.06	250	m
6.00 - Average		

2 days		
A	B	C
6.93 6.27 7.59 5.73	270	m
5.48 5.56 5.56 6.77	230	m
6.93 5.89 6.02 5.23	300	m
5.69 6.81 6.97 6.23	310	m
D D D D	-	-
6.23 - Average		

3 days		
A	B	C
6.35 6.02 5.23 5.40	250	f
6.52 5.52 6.31 5.81	330	m
6.10 5.27 5.81 6.81	250	f
5.94 4.90 5.35 6.43	310	m
6.14 6.64 6.60 6.52	330	m
5.98 - Average		

5 days		
A	B	C
5.31 5.81 5.06 4.86	300	m
6.14 6.14 5.23 5.73	250	m
4.81 4.81 4.86 6.47	290	m
6.39 4.57 6.64 6.14	330	m
5.44 6.02 6.35 5.31	230	f
5.60 - Average		

Medium Chromic Catgut Size 2 (contd.)

7 days		
A	B	C
2.82	280	m
6.35		
5.85		
4.98		
3.98	230	m
4.36		
2.60		
6.64		
6.23	290	m
6.14		
6.85		
5.89		
5.60	270	m
6.64		
6.10		
5.73		
6.35	240	m
6.64		
6.23		
5.60		
5.58 - Average		

10 days		
A	B	C
3.15	350	m
3.32		
4.90		
5.81		
6.31	320	m
5.60		
4.65		
3.82		
4.81	300	m
6.06		
2.86		
5.73		
6.39	310	m
3.40		
5.15		
5.64		
6.06	300	m
5.64		
4.65		
5.31		
4.96 - Average		

15 days		
A	B	C
2.91	290	m
2.49		
4.57		
2.49		
2.45	320	m
3.74		
1.83		
2.78		
3.40	300	m
1.62		
4.23		
4.81		
2.20	300	m
4.15		
3.32		
3.78		
4.32	300	m
2.66		
3.98		
3.11		
3.24 - Average		

20 days		
A	B	C
1.16	320	m
5.15		
2.91		
2.24		
3.15	210	f
1.74		
2.49		
4.32		
2.91	280	f
2.24		
1.16		
0.42		
1.49	230	f
2.24		
3.82		
4.73		
2.91	190	f
4.98		
2.57		
4.07		
2.84 - Average		

Medium Chromic Catgut Size 2 (contd.)

25 days		
A	B	C
2.08 3.78 4.57 0.00	230	m
2.16 1.95 2.74 0.00	260	m
1.70 3.11 0.83 0.42	320	m
1.29 2.49 2.74 3.90	300	m
1.49 1.49 2.95 0.42	240	m
2.01 - Average		

30 days		
A	B	C
0.29 0.66 0.17 0.00	290	m
0.50 0.79 0.33 1.49	270	m
0.17 1.70 0.00 0.00	300	m
2.62 1.99 1.12 0.00	260	m
2.12 0.37 0.71 0.00	270	m
0.75 - Average		

35 days		
A	B	C
0.73 1.31 0.00 0.00	250	m
0.15 0.73 0.29 0.00	300	m
0.48 0.54 0.00 0.00	330	m
1.47 1.97 0.81 0.00	260	m
0.19 0.73 0.60 0.00	240	m
0.50 - Average		

40 days		
A	B	C
0.50 1.02 0.00 0.00	280	m
0.42 0.00 0.00 0.00	350	m
1.99 0.00 0.00 0.00	300	f
0.00 0.00 0.00 0.00	250	f
0.00 0.00 0.00 0.00	250	m
0.20 - Average		

<u>Initial Strengths of Medium Chromic Catgut</u>

Size 5/0	Size 3/0	Size 0	Size 2
0.52	1.81	3.75	5.68
0.57	1.76	3.06	6.57
0.49	2.10	2.97	5.20
0.36	1.55	3.68	6.57
0.69	1.89	3.12	5.82
0.41	1.39	4.85	6.22
0.36	1.30	3.21	5.60
0.52	0.97	3.59	6.92
0.48	1.64	3.86	6.84
0.51	2.10	3.13	6.44
0.41	2.02	3.68	5.41
0.54	1.85	4.58	6.13
0.55	1.89	3.84	5.15
0.32	1.72	3.37	4.89
0.39	1.43	2.86	6.79
0.43	1.43	3.53	5.20
0.38	1.64	3.60	6.57
0.48	1.30	3.33	5.15
0.51	1.60	4.07	7.10
0.46	1.76	3.91	5.68
0.46	1.66	3.60	6.00

Data Summarised in Table VIII

Plain Catgut Size 3/0 in Incised Muscle

1 day		
A	B	C
0.89 1.27 1.64 2.01	180	m
1.31 1.56 1.68 1.89	170	m
1.41 1.58 1.47 1.41	180	m
0.44 1.45 1.16 1.29	120	m
0.95 1.60 0.85 1.16	150	m
1.35 - Average		

2 days		
A	B	C
0.93 1.25 1.60 1.74	170	m
1.10 1.27 1.35 1.39	160	m
1.16 1.60 1.45 1.08	180	m
1.35 1.33 0.75 0.48	140	f
1.14 0.98 1.41 0.64	130	f
1.20 - Average		

3 days		
A	B	C
0.12 0.12 0.71 0.83	150	m
0.77 1.18 0.81 0.50	130	m
0.73 0.83 0.89 0.66	130	m
0.71 1.47 0.95 1.35	180	f
1.04 1.02 1.45 0.93	180	f
0.85 - Average		

5 days		
A	B	C
1.60 0.77 0.71 0.10	120	m
0.19 0.17 0.10 0.10	120	m
0.77 0.27 1.04 1.70	180	m
0.75 0.62 0.10 0.48	180	m
0.81 0.66 0.27 0.12	150	f
0.57 - Average		

Plain Catgut Size 3/0 in Incised Muscle (contd.)

7 days		
A	B	C
0.08 0.11 0.34 0.74	200	f
0.00 0.00 0.07 0.23	150	f
0.24 0.91 0.29 1.06	200	m
1.49 0.71 1.06 1.39	160	f
0.46 0.12 0.64 0.60	160	f
0.53 - Average		

10 days		
A	B	C
0.77 0.54 0.56 0.19	140	f
0.85 0.93 0.60 0.12	160	f
0.27 1.12 0.25 0.00	150	m
0.20 0.35 0.00 0.00	150	f
0.32 0.42 0.64 0.44	150	f
0.43 - Average		

15 days		
A	B	C
0.00 0.20 0.26 0.88	160	m
0.49 0.13 0.62 0.72	180	f
0.00 0.12 0.00 0.00	150	f
0.00 0.00 0.05 0.18	160	f
0.00 0.09 0.77 0.06	140	f
0.23 - Average		

Medium Chromic Catgut Size 3/0 in Incised Muscle

1 day		
A	B	C
2.12 2.24 1.91 2.20	150	m
2.57 1.87 1.74 2.37	160	m
1.99 1.95 2.53 1.70	180	m
1.99 2.03 1.74 1.41	150	m
2.12 2.24 1.83 1.91	140	f
2.02 - Average		

2 days		
A	B	C
1.83 1.58 1.49 1.66	150	m
1.70 1.66 1.45 1.00	150	m
1.78 1.78 1.99 2.08	120	f
1.99 2.28 2.16 1.99	140	f
1.83 1.78 1.66 1.37	170	m
1.75 - Average		

3 days		
A	B	C
1.83 1.41 2.03 1.66	230	m
1.74 1.37 1.37 1.58	180	f
1.37 1.95 1.62 1.66	190	f
2.03 2.12 1.62 1.37	150	m
1.91 1.91 1.78 1.62	140	m
1.70 - Average		

5 days		
A	B	C
1.62 2.12 1.49 1.83	220	f
1.37 1.45 1.25 1.49	210	f
1.41 1.41 1.83 1.70	140	m
1.87 1.83 1.54 2.28	150	m
1.49 1.91 1.87 1.91	120	f
1.68 - Average		

Medium Chromic Catgut Size 3/0 in Incised Muscle (contd.)

7 days		
A	B	C
1.56 1.83 1.99 1.81	170	f
2.08 1.56 2.08 1.45	260	m
1.33 1.62 1.00 1.83	200	f
1.91 0.58 1.41 1.37	180	m
1.33 1.54 1.49 1.74	170	m
1.58 - Average		

10 days		
A	B	C
1.68 1.49 1.47 0.60	270	m
1.29 0.68 1.54 1.56	180	f
1.27 1.76 1.45 1.25	240	m
1.14 1.64 0.87 1.58	150	f
1.02 1.51 1.72 1.64	150	m
1.36 - Average		

15 days		
A	B	C
0.79 1.25 0.54 1.76	240	m
0.73 1.49 1.31 1.43	170	m
0.62 1.25 1.16 0.77	160	m
1.70 1.00 1.12 0.77	210	f
1.47 0.46 0.83 1.43	140	f
1.09 - Average		

20 days		
A	B	C
0.08 0.33 0.31 0.73	210	m
0.50 1.62 0.93 0.66	220	m
0.66 0.33 1.85 D	220	m
0.44 0.54 1.10 1.27	170	f
0.42 1.37 1.35 0.58	240	m
0.80 - Average		

Medium Chromic Catgut Size 3/0 in Incised Muscle (contd.)

25 days		
A	B	C
0.12 0.15 0.42 0.64	170	f
0.91 1.27 0.27 1.00	240	m
0.42 0.58 D D	200	f
0.37 0.66 0.73 0.56	210	m
0.35 0.58 0.77 0.23	220	m
0.56 - Average		

30 days		
A	B	C
0.58 0.42 0.77 0.00	250	f
0.17 0.10 0.15 0.71	180	f
0.10 0.17 0.41 0.00	230	m
0.00 0.85 0.78 0.84	190	m
0.25 0.09 0.32 0.00	220	m
0.34 - Average		

Data Summarised in Table IX

2 days		
A	B	C
0.89 1.08	250	m
1.39 1.02	220	m
1.54 1.91	250	m
0.81 1.16	150	m
1.00 1.31	190	m
1.16 1.95	190	m
1.22 1.25	210	m
0.93 1.37	150	m
1.10 1.76	230	m
1.06 1.66	210	m
1.28 - Average		

3 days		
A	B	C
1.87 0.91	180	f
0.42 0.73	200	f
0.50 0.75	210	m
0.08 0.21	210	m
1.87 0.93	170	f
0.31 0.75	170	f
1.62 1.39	180	f
1.10 1.72	250	m
1.06 1.76	240	m
D D	-	-
1.00 - Average		

5 days		
A	B	C
0.21 0.21	290	m
0.37 1.04	280	m
0.29 0.58	310	m
0.15 0.00	290	m
0.44 0.15	270	m
1.74 0.98	210	m
1.35 0.58	180	m
0.15 0.56	160	m
D D	-	-
D D	-	-
0.55 - Average		

7 days		
A	B	C
0.15 0.15	200	m
0.98 1.00	210	m
0.15 0.96	190	m
0.06 0.66	230	m
0.50 0.08	180	m
0.54 0.08	180	m
0.33 0.71	160	m
0.77 0.08	200	m
0.29 0.33	220	m
0.81 0.87	190	m
0.47 - Average		

Data Summarised in Table IX (contd.)

10 days			15 days		
A	B	C	A	B	C
0.13 0.00	250	m	0.18 0.00	240	m
0.89 0.48	260	m	0.43 0.03	230	m
0.27 0.00	250	m	0.03 0.00	280	m
0.00 0.00	230	m	0.00 0.00	260	m
0.00 0.00	210	m	0.00 0.00	230	m
0.10 0.00	200	m	0.05 0.00	230	m
0.00 0.00	210	m	0.30 0.09	200	m
0.00 0.00	230	m	0.20 0.00	230	m
0.23 0.00	230	m	0.03 0.00	220	m
0.21 0.10	250	m	D D	-	-
0.12 - Average			0.07 - Average		

Data Summarised in Table X

Tensile Strength of Plain Catgut Size 3/0

No Sensitisation		Plain Sensitisation		Medium Chromic Sensitisation	
2 days	7 days	2 days	7 days	2 days	7 days
1.65	0.55	1.06	0.00	1.56	0.57
1.49	0.55	1.08	0.00	1.46	0.36
1.19	0.53	1.41	0.15	0.49	0.13
0.91	0.26	0.83	0.05	1.42	0.00
1.94	1.19	1.49	0.00	1.17	1.24
1.68	0.80	0.89	0.00	0.98	1.11
1.43	0.71	0.98	0.33	0.96	0.92
1.13	0.42	0.93	0.08	0.94	0.30
1.75	0.88	1.00	0.00	1.50	1.25
1.43	0.82	0.33	0.00	1.36	1.02
1.15	0.40	0.46	0.00	1.19	0.96
1.13	0.32	0.71	0.07	D	0.65
1.33	0.92	0.89	0.00	1.40	1.17
1.25	0.86	1.18	0.00	1.31	1.05
1.21	0.61	0.91	0.00	1.00	0.65
1.17	0.05	1.29	0.00	1.63	0.00
1.49	1.17	1.41	D	1.60	1.20
1.45	0.82	1.49	D	1.27	0.94
1.15	0.53	0.64	D	1.02	0.13
0.87	0.51	0.77	D	1.23	0.13
1.72	0.74	1.29	0.89	1.48	1.26
1.27	0.65	0.93	0.37	1.42	1.03
1.25	0.17	0.81	1.02	1.31	0.80
0.85	0.11	0.30	0.69	0.59	0.76
1.57	0.98	0.91	0.00	1.69	1.07
1.03	0.34	1.06	0.33	1.63	0.69
0.89	0.19	0.88	0.85	1.52	0.65
0.57	0.07	1.34	0.98	1.50	0.26
1.47	1.01	0.98	1.52	1.77	0.97
1.40	0.63	0.73	0.75	1.40	0.30
1.08	0.13	1.59	0.73	1.07	0.10
0.85	0.00	0.53	0.00	0.88	0.00
1.42	1.12	0.15	0.23	1.60	1.26
1.35	0.92	1.31	0.37	1.09	0.44
1.12	0.40	1.41	0.15	0.73	0.11
1.12	0.34	1.49	0.58	0.65	0.00
1.49	1.11	1.29	0.00	D	1.09
1.17	0.49	0.86	0.00	D	0.82
0.86	0.44	0.81	0.75	D	0.57
0.85	0.40	0.38	1.04	D	0.10
1.25	0.58	0.97	0.33	1.22	0.65

Tensile Strength of Medium Chromic Catgut Size 3/0

No Sensitisation		Medium Chromic Sensitisation		Plain Sensitisation	
7 days	25 days	7 days	25 days	7 days	25 days
1.76	0.71	1.25	1.95	1.89	0.76
1.52	0.42	1.47	1.41	1.79	0.53
1.31	0.40	1.93	1.33	1.60	0.28
1.08	0.03	1.18	1.25	1.18	0.55
1.70	0.89	1.43	1.35	0.56	1.13
1.00	1.11	1.79	0.91	1.52	0.76
0.93	1.05	1.29	0.71	1.89	0.63
0.87	0.96	1.85	1.39	1.76	0.59
1.74	0.76	1.79	0.52	1.89	1.12
1.74	0.76	1.62	0.83	1.74	0.98
1.72	0.46	1.39	1.18	1.58	0.61
1.72	0.93	1.25	0.42	1.47	0.00
1.58	0.71	1.99	0.44	1.60	0.78
1.74	0.26	1.39	0.64	1.60	0.28
1.64	0.11	1.39	1.08	1.49	0.03
1.47	0.76	1.93	0.73	1.47	0.15
1.66	0.57	D	0.52	1.83	1.44
1.00	0.30	D	0.39	1.70	1.09
0.89	0.82	D	0.58	1.22	0.73
0.77	1.05	D	1.56	1.14	0.63
1.52	0.71	1.85	1.20	2.08	0.96
1.66	0.38	1.31	1.12	1.54	0.34
1.85	0.34	1.64	1.04	1.37	1.09
1.97	0.13	1.81	1.18	1.00	1.34
1.22	1.09	1.83	1.18	1.95	0.94
1.45	1.03	1.60	1.06	1.70	0.92
1.91	0.55	1.60	0.66	1.85	0.46
2.08	0.19	1.87	0.62	1.41	1.00
1.45	0.15	2.08	0.13	1.95	0.63
1.93	0.17	1.56	0.29	1.95	1.14
1.97	0.13	1.16	0.66	1.87	0.70
2.08	0.13	1.64	0.58	1.47	0.00
1.45	0.59	0.96	0.42	1.72	0.87
1.60	0.21	1.20	0.73	1.56	0.63
1.64	0.10	1.47	0.00	1.45	0.26
1.72	0.13	1.93	0.54	1.37	0.13
1.78	0.37	1.70	0.73	D	0.53
1.72	0.36	1.56	1.39	D	0.57
1.27	0.17	1.83	1.22	D	0.55
1.22	0.00	1.89	0.00	D	0.00
1.53	0.50	1.60	0.85	1.59	0.65

Data Summarised in Table XI

Tensile Strength of Plain Catgut Size 3/0

3 days		7 days	
38°C.	30°C.	38°C.	30°C.
1.35	1.87	0.69	1.37
1.16	1.56	1.04	1.16
1.08	1.35	1.18	1.12
0.96	0.44	1.02	1.08
1.52	1.68	0.10	1.58
1.43	1.62	1.02	1.37
1.25	1.58	1.47	1.20
0.37	1.37	0.00	0.98
1.29	1.60	0.21	1.47
0.96	1.58	1.37	1.41
0.85	1.29	0.42	1.12
0.50	1.04	0.00	1.02
1.70	1.35	0.62	1.54
1.16	1.31	1.31	1.52
1.06	1.12	0.93	1.37
0.75	1.10	0.00	1.35
1.39	1.56	0.58	1.49
1.33	1.31	0.89	1.43
1.22	1.37	0.31	1.35
1.06	1.16	0.56	1.12
1.25	1.43	1.35	1.64
1.02	1.00	0.38	1.22
0.58	1.31	0.32	1.04
0.54	1.14	0.15	0.75
1.33	1.45	1.42	1.39
0.89	1.45	1.29	1.16
0.79	1.29	0.50	1.00
0.17	1.20	0.23	0.48
1.37	1.54	0.40	1.33
1.33	1.35	0.52	1.27
0.93	1.22	0.25	1.04
0.66	1.45	0.42	0.98
1.47	1.37	0.42	1.31
1.29	1.18	1.15	1.10
1.25	1.18	1.21	0.83
0.85	1.12	0.69	0.10
1.52	1.54	0.44	1.37
1.00	1.45	0.19	1.08
0.93	1.45	0.17	0.29
0.19	1.43	0.65	0.17
1.05	1.35	0.65	1.14

Data Summarised in Table XII

Tensile Strength of Plain Catgut Size 3/0 Isolated from Tissue Cells in vivo

"Control" Implants				
2 days	5 days	10 days	15 days	25 days
1.32	1.05	0.15	0.29	0.00
1.28	0.56	0.17	0.00	0.00
1.63	0.48	0.00	0.00	0.00
1.17	0.91	0.44	0.00	0.00
1.28	1.47	0.33	0.00	0.00
1.59	0.44	0.61	0.00	0.00
1.28	0.85	0.33	0.00	0.00
0.80	0.48	0.25	0.00	0.00
1.09	0.97	0.31	0.05	0.00
0.93	0.81	0.42	0.12	0.00
0.93	0.32	0.50	0.00	0.00
0.62	0.30	0.21	0.00	0.00
1.26	0.01	0.37	0.12	0.00
1.58	0.75	0.12	0.00	0.00
1.21	0.64	0.00	0.00	0.00
0.78	0.58	0.25	0.00	0.00
1.40	0.71	0.17	0.21	0.00
1.65	0.62	0.12	0.00	0.00
1.13	0.46	0.24	0.00	0.00
1.05	0.73	0.00	0.00	0.00
1.20	0.66	0.25	0.04	0.00

"Millipore" Implants				
2 days	5 days	10 days	15 days	25 days
1.08	1.63	1.45	0.71	0.00
1.39	1.09	0.50	0.66	0.00
2.26	1.70	1.25	0.42	0.00
1.88	0.66	1.08	0.66	0.00
2.35	1.46	1.08	0.60	0.00
1.54	1.46	0.98	0.82	0.00
1.54	0.78	1.00	0.54	0.00
1.68	0.95	0.54	0.45	0.00
1.32	1.39	1.12	0.33	0.00
1.52	1.31	0.89	0.50	0.00
1.88	1.58	0.98	0.89	0.00
1.06	0.39	1.25	0.25	0.00
1.54	1.41	0.85	0.73	0.00
1.64	1.53	1.33	0.63	0.00
1.97	0.41	0.73	0.68	0.00
1.08	1.07	0.73	0.49	0.00
1.45	1.09	0.77	0.73	0.00
1.08	0.95	0.89	0.58	0.00
0.67	1.89	0.82	0.72	0.00
1.28	1.43	1.00	0.89	0.00
1.51	1.21	0.96	0.61	0.00

Data Summarised in Table XIII

Tensile Strength of Plain Catgut Size 3/0

1 day	2 days	3 days	5 days	7 days
1.20	1.27	1.56	1.06	0.79
1.22	1.51	1.91	0.89	0.68
1.40	1.51	1.54	1.39	1.42
1.76	1.62	1.58	1.20	1.10
1.78	1.41	1.76	1.43	0.54
1.49	1.47	1.27	0.52	0.73
1.75	1.76	1.60	0.92	0.89
1.44	1.97	1.58	0.75	1.21
1.44	1.25	1.37	1.02	1.02
1.84	1.37	1.41	1.56	0.50
1.76	1.47	1.49	1.43	0.50
1.76	1.85	1.47	1.29	1.44
1.10	1.66	1.89	1.20	1.62
0.98	1.49	1.76	1.66	1.25
1.68	1.39	0.95	1.00	0.64
1.42	1.31	1.39	1.74	0.80
1.64	1.47	1.41	1.39	1.15
1.40	1.22	1.39	1.02	0.85
1.08	1.49	1.54	0.93	1.31
1.18	1.72	1.18	1.35	1.33
1.27	1.37	1.47	1.66	1.46
1.60	1.56	1.39	1.62	1.20
1.62	1.41	1.18	1.20	0.46
1.64	1.43	1.29	1.64	0.52
1.64	1.45	1.85	0.66	1.54
1.78	1.74	1.14	0.85	0.83
1.48	1.56	1.14	1.37	0.64
1.04	1.66	1.58	1.27	1.54
0.90	1.54	1.78	1.66	1.31
0.90	1.43	1.31	1.60	0.62
1.76	1.85	1.39	1.20	1.42
1.70	1.83	1.27	0.96	0.56
1.49	1.95	1.49	0.52	0.75
0.76	1.43	1.37	1.18	1.54
1.60	1.45	1.45	1.31	1.54
1.60	1.51	1.81	0.73	0.54
1.54	1.41	1.29	1.29	0.42
1.60	1.27	1.37	1.18	0.58
1.70	1.58	1.58	1.12	1.47
1.82	1.08	1.49	1.37	1.29
1.47	1.52	1.47	1.20	1.00

Tensile Strength of Plain Catgut Size 3/0 (contd.)

10 days	15 days	20 days	25 days
1.39	1.25	0.93	0.57
1.25	0.71	0.56	0.15
0.85	0.29	0.31	0.14
1.52	0.52	0.50	0.15
0.52	0.60	0.10	0.29
1.04	0.52	0.58	0.11
0.93	0.52	0.44	0.75
1.10	0.35	0.60	0.18
1.25	0.87	1.00	0.19
0.85	0.13	0.66	0.05
1.35	0.54	0.95	0.19
0.98	0.56	0.10	0.15
0.93	0.23	0.10	0.15
0.81	0.35	0.89	0.14
1.00	0.37	0.66	0.10
0.54	1.16	1.12	0.86
1.14	0.54	0.62	0.19
1.14	0.46	0.46	0.15
1.10	0.37	0.10	0.12
1.04	0.60	0.85	0.14
1.22	0.79	0.65	0.20
0.62	0.71	0.13	0.10
1.04	1.04	1.03	0.14
0.87	0.19	0.90	0.42
0.68	0.29	0.63	0.29
0.73	0.08	1.15	0.19
1.06	0.66	0.49	0.34
0.56	0.66	0.55	0.24
0.85	0.12	0.98	0.21
0.93	0.33	0.41	0.15
1.06	0.17	0.69	0.32
1.00	0.56	0.86	0.14
1.04	0.46	0.28	0.30
1.27	0.39	0.88	0.15
0.71	0.27	0.57	0.24
1.22	0.46	0.13	0.27
0.75	0.56	0.47	0.50
0.79	0.75	0.08	0.18
1.35	0.95	0.53	0.21
0.87	0.71	0.13	0.29
0.98	0.53	0.58	0.24

Data Summarised in Table XIII

Tensile Strength of Medium Chromic Catgut Size 3/0

1 day	2 days	3 days	5 days	7 days
1.99	1.74	1.49	1.29	2.20
2.03	1.99	1.54	1.04	2.16
1.99	1.29	1.91	1.66	1.95
1.83	1.29	1.87	2.03	2.32
1.95	1.54	1.62	1.91	1.70
1.08	1.00	1.00	1.45	1.25
1.58	1.25	1.83	1.04	1.70
1.87	1.45	1.87	0.91	1.66
1.62	2.08	1.62	2.28	1.99
1.70	1.99	1.66	1.70	1.95
1.91	1.95	1.95	1.74	1.99
1.87	1.49	2.16	1.16	2.08
1.54	1.78	1.58	1.78	1.33
1.87	1.37	1.70	1.54	1.91
1.91	1.41	2.12	1.83	2.12
1.87	1.33	2.03	1.70	2.03
2.08	1.54	1.91	1.62	1.91
2.16	1.29	1.49	1.29	2.08
1.74	1.74	1.49	1.33	1.70
1.91	1.58	1.58	1.45	1.49
1.58	1.54	1.95	1.99	0.98
1.61	1.99	1.29	1.87	1.39
1.61	1.29	0.91	1.29	1.18
2.08	0.95	1.70	1.95	1.06
1.99	1.37	1.33	1.87	2.37
2.08	1.41	1.00	1.37	1.25
1.83	1.54	0.91	1.91	1.29
1.78	1.83	1.49	1.87	2.32
1.74	1.58	1.33	1.83	1.99
1.74	1.58	1.49	1.70	1.66
1.87	1.91	1.25	1.83	1.08
1.70	1.87	1.29	1.54	1.04
1.54	1.12	1.08	1.54	1.43
1.41	1.83	1.58	1.78	1.22
1.87	1.78	1.33	2.20	1.74
1.41	1.33	1.33	1.87	1.87
1.29	1.70	1.54	1.78	1.99
1.29	1.66	1.49	1.99	2.08
1.75	1.58	1.37	1.95	2.03
1.37	1.45	1.49	2.20	2.08
1.75	1.56	1.54	1.68	1.74

Tensile Strength of Medium Chromic Catgut Size 3/0 (contd.)

10 days	15 days	20 days	25 days	30 days
2.03	1.62	1.29	1.70	1.83
1.95	1.70	1.78	1.99	1.78
1.37	2.03	1.87	1.99	1.29
1.66	1.99	1.78	1.49	2.45
1.49	1.45	1.29	1.58	1.74
1.91	1.95	1.41	1.74	1.95
1.41	1.95	1.74	1.70	2.03
1.70	1.37	1.66	1.78	1.54
1.33	1.54	1.58	1.83	1.66
1.74	1.54	1.49	1.78	1.62
1.78	1.70	1.20	2.03	1.91
1.95	1.58	1.29	1.62	1.66
1.74	1.83	1.54	1.62	1.70
1.70	1.91	1.45	1.66	2.08
1.95	1.66	1.54	1.70	1.87
1.62	1.62	1.62	1.74	2.16
1.62	1.66	1.29	1.95	1.66
1.66	1.70	1.41	1.99	1.66
1.58	1.83	1.58	1.83	1.74
1.54	1.62	1.58	1.78	1.62
1.95	1.25	1.41	1.87	2.41
2.12	1.41	1.25	0.37	2.16
2.03	1.91	2.37	1.49	1.49
1.70	1.37	2.37	1.49	1.91
2.03	1.62	2.08	1.78	1.29
1.66	1.95	1.36	1.78	1.08
2.03	1.54	1.95	1.74	1.25
1.99	1.37	1.36	1.58	1.29
2.20	1.78	2.16	1.78	1.45
2.08	1.58	1.99	1.54	1.37
1.66	1.33	2.03	1.41	1.74
2.12	2.03	1.66	1.58	1.37
1.54	1.74	1.66	1.78	1.33
1.54	1.78	1.45	1.70	1.91
1.74	1.37	1.58	1.41	1.45
1.70	1.87	2.12	1.62	1.99
1.58	1.83	2.08	1.66	2.24
2.20	1.87	1.66	1.66	1.74
1.83	1.66	1.91	1.54	1.33
1.58	1.74	1.33	1.74	1.66
1.78	1.68	1.65	1.70	1.71

Data Summarised in Table XIV

Tensile Strength of Plain Catgut Size 3/0 after 10 Days

Non-Sterile Saline	Sterile Saline	Non-Sterile Saline + 0.002% PMN
1.32	1.68	1.49
1.18	1.58	1.39
1.18	1.49	1.37
0.77	0.54	0.91
1.14	1.31	1.02
0.87	0.98	0.77
0.32	1.10	0.85
1.28	0.91	1.02
1.12	0.68	1.08
1.24	1.18	1.22
1.46	0.56	1.06
1.38	0.60	1.25
0.33	1.00	1.33
0.89	0.62	0.98
0.63	0.89	0.85
1.06	1.10	0.83
0.77	0.83	1.20
1.16	1.25	0.79
0.53	0.68	1.16
0.89	0.87	1.18
0.98	0.99	1.09

Data Summarised on pp. 85 and 86

Effect of Plasma, Dextran and P.V.P. Solutions on the Tensile Strength of Plain Catgut Size 3/0 after 10 days

Plasma	Dextran	P.V.P.
1.74	1.35	1.39
1.72	1.08	0.73
1.56	1.43	0.93
1.51	1.27	1.51
1.37	1.25	1.58
1.72	1.47	1.06
1.49	1.08	1.27
1.33	1.31	0.73
1.56	1.22	1.41
1.76	1.22	1.18
1.64	1.70	1.06
1.58	1.89	1.66
1.58	1.81	1.56
1.56	1.85	0.56
1.51	1.87	0.85
1.35	1.72	1.81
1.56	1.64	1.49
1.76	1.64	1.37
1.68	1.70	0.73
1.49	1.56	1.14
1.57	1.50	1.20

Data Summarised in Table XV

Effect of Streptokinase on the Tensile Strength of Plain Catgut Size 3/0

Saline	Saline + SK	Plasma	Plasma + SK
0.54	0.95	1.66	1.26
0.79	0.87	1.35	1.89
0.27	0.58	1.62	1.81
1.12	0.44	1.41	1.64
1.06	0.79	1.64	1.66
0.98	0.95	1.51	1.59
0.56	0.95	1.68	1.43
0.56	0.71	0.64	1.87
0.33	0.68	1.68	1.78
1.10	0.99	1.45	1.87
0.46	0.58	1.74	1.87
0.52	0.75	1.53	1.37
0.12	0.93	1.51	1.51
0.91	0.87	1.53	1.51
1.33	0.58	1.47	1.54
1.25	0.56	1.47	1.87
0.87	0.75	1.30	1.93
1.45	0.89	1.37	1.87
0.89	0.52	1.24	1.16
0.75	0.75	1.37	1.20
0.79	0.75	1.46	1.63

Data Summarised in Table XVI

Effect of Hyaluronidase on Tensile Strength of Plain Catgut Size 3/0

Saline	Saline + 30 units/ml. Hyaluronidase	Saline + 60 units/ml. Hyaluronidase
0.54	0.98	2.08
0.79	1.22	0.75
0.27	1.39	0.85
1.12	1.20	0.52
1.06	1.45	1.41
0.98	1.18	1.87
0.56	1.14	2.08
0.56	1.31	0.68
0.33	1.02	1.85
1.10	1.43	1.27
0.46	1.06	0.71
0.52	1.44	0.27
0.12	1.46	1.78
0.91	1.39	1.85
1.33	1.23	1.60
1.25	1.17	1.54
0.87	0.96	1.72
1.45	1.00	1.45
0.89	1.31	1.35
0.75	1.31	0.75
0.79	1.23	1.32

Data Summarised in Table XVII

Tensile Strength of Catgut Size 3/0 in 1.0% Pepsin in Vitro

Pepsin pH 1.6			
Plain		Medium Chromic	
1 day	5 days	1 day	5 days
0.25	0.00	1.15	0.00
0.10	0.00	0.74	0.00
0.12	0.00	0.80	0.00
0.78	0.00	0.44	0.00
0.49	0.00	0.71	0.00
0.10	0.00	0.77	0.00
0.12	0.00	1.05	0.00
0.12	0.00	0.94	0.00
0.74	0.00	0.32	0.00
0.29	0.00	0.99	0.00
0.10	0.00	0.99	0.00
0.12	0.00	0.86	0.00
0.10	0.00	0.53	0.00
0.10	0.00	1.15	0.00
0.31	0.00	0.77	0.00
0.12	0.00	1.00	0.00
0.31	0.00	0.68	0.00
0.42	0.00	0.66	0.00
0.12	0.00	1.08	0.00
0.39	0.00	0.78	0.00
0.26	0.00	0.82	0.00

Data Summarised in Table XVII (contd.)

Tensile Strength of Catgut Size 3/0 in Trypsin in Vitro

Trypsin pH 7.2			
Plain		Medium Chromic	
1 day	5 days	1 day	5 days
0.52	0.00	1.31	0.10
0.30	0.00	0.98	0.27
0.18	0.00	0.63	0.12
0.21	0.00	1.31	0.75
0.76	0.00	0.98	0.12
0.28	0.00	1.44	0.42
0.00	0.00	0.96	0.27
0.00	0.00	1.01	0.39
0.62	0.00	1.01	0.25
0.14	0.00	0.68	0.10
0.82	0.00	0.50	0.25
0.11	0.00	1.49	0.10
0.16	0.00	0.85	0.10
0.51	0.00	0.96	0.56
1.08	0.00	1.03	0.60
0.13	0.00	0.98	0.12
0.85	0.00	0.76	0.12
0.31	0.00	1.07	0.10
0.62	0.00	1.00	0.64
0.59	0.00	1.31	0.10
0.41	0.00	1.01	0.27